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ELEMENTARY
BOTANY
FOR SOUTH AFRICA

EDMONDS AND MARLOTH

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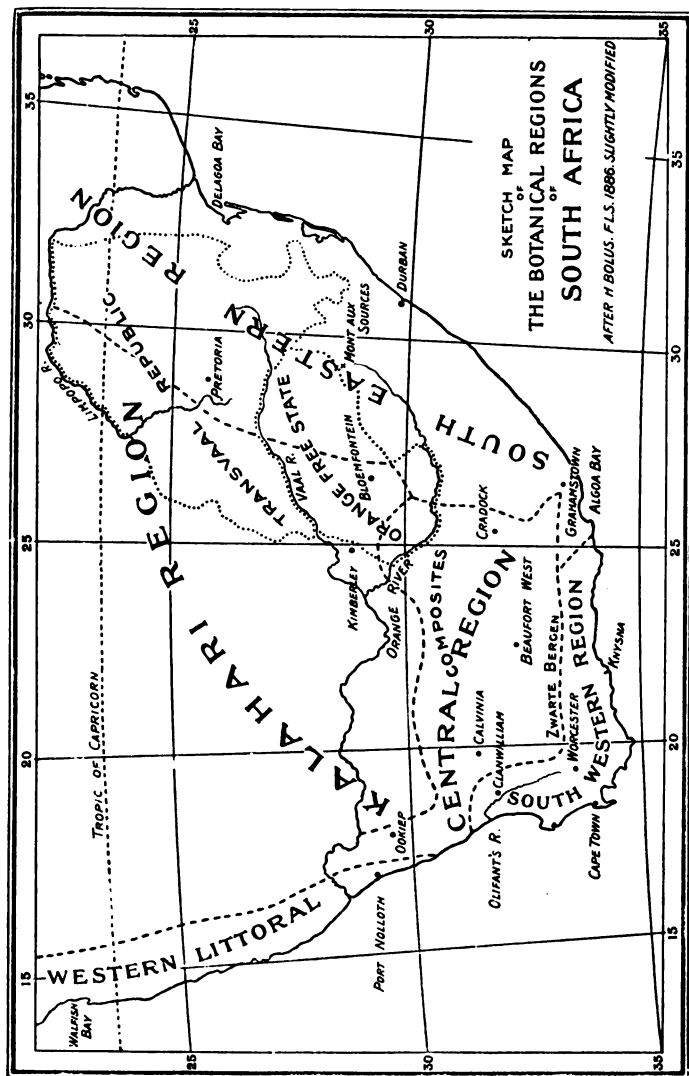
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ELEMENTARY BOTANY
FOR SOUTH AFRICA

THEORETICAL AND PRACTICAL

BY

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LONGMANS, GREEN, & CO.

LONDON, NEW YORK, AND BOMBAY

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PREFACE

THE object of this text-book is as far as possible to give a general idea of the fundamental facts and principles of the science. In many elementary works the greater part of the book is taken up with mere structural details, the Physiology of the Plants being relegated to a short chapter at the end. I have endeavoured, whilst tracing up the growth and development of the plant from the seed, to treat of the functions of each organ at the same time as its description.

Through the liberality of the publishers, the book is well supplied with diagrams. It will not do, however, for the student to trust to these alone. No science can be properly studied from mere book-work, and this is especially true of such a science as Botany, which deals with various forms of natural objects. The student is strongly urged from the first to carefully examine specimens. A sharp penknife and a simple lens, which will only cost a few shillings, are all the apparatus required for dissecting and examining most flowers, and the commonest plants around us will well serve the student's purpose.

For some parts of the subject—as, for instance, the examination of Cellular Tissues—a microscope is needful. An excellent instrument can be obtained at any of the well-known makers' for about five or six pounds.

The student should also especially accustom himself to writing out descriptions of plants according to the model given at the close of the book.

H. EDMONDS.

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ERRATA.

- Page 16, Fig. 22, for "*Coccino-discus*" read "*Coscinodiscus*."
- „ 57, last five lines should stand at top of page.
- „ 59, Fig. 90, for "*cuxifolius*" read "*buxifolius*."
- „ 85, after line 10, insert new par. : "**Definite Inflorescences.**—
The general name for these is *cyme*."
- „ 95, last line, for "fig. 257" read "fig. 258."
- „ 124, line 12, for "Mapelia" read "Stapelia."
- „ 139, Fig. 217 should be inverted.
- „ 140, line 7, "**Oxalis**" should be in italics.
- „ 142, line 17, for "LEGUMINOSÆ" read "LEGUMINOSÆ."
- „ 148, line 1, "**Cliffortia**" should be in italics.
- „ 148, line 12, for "**Ovary** of 4 to 7 (mostly 5). **Carpels**, which"
read "**Ovary** of 4 to 7 (mostly 5) **carpels**, which."
- „ 149, last line, delete "237."
- „ 154, line 1, after "**Senecioides**" insert "(fig. 243)."
- „ 156, line 4, for "fig. 136" read "fig. 138."
- „ 175, line 4 from bottom, for "*Iria*" read "*Ixia*."
- „ 194, line 22, for "hava" read "have."
- „ 195, line 3, for "grandular" read "glandular."
- „ 198, column 3, line 27, for "Geele bloempjes" read "Geele bloemetjes."
- „ 199, column 1, line 7 from bottom, for "*Iria*" read "*Ixia*."
- „ 201, column 2, line 6 from bottom, for "**Veanoniaceæ**" read "**Vernoniaceæ**."
- „ 203, column 1, line 20, after "93" insert "142."
- „ 204, column 2, line 29, for "173" read "153."
- „ 205, column 2, line 25, after "24" insert "56."

under a microscope prove to be true plants (*Protococcus pluvisialis*), each being a little rounded mass containing green particles. After watching for some time, however, it will be seen that some of these plants change their form, becoming more pear-shaped, at the same time giving off two very minute threads or cilia. These are thrown into rapid motion, propelling the plant

ELEMENTARY BOTANY

CHAPTER I.

INTRODUCTORY—DEFINITION AND SCOPE OF THE SCIENCE.

BOTANY is the science which deals with those special forms of living organisms known as Plants. This at once raises the question—What do we mean by a plant? The higher forms of animal and vegetable life can be easily distinguished the one from the other; but when we descend to the lower forms we find it most difficult, if not impossible, to draw a line of demarcation between them.

The old distinction between the three kingdoms of nature was a simple one: minerals grow—plants live and grow—animals move, live, and grow. Putting aside for a moment the question as to whether minerals really grow, the phenomena of motion cannot be accepted as defining the difference between the two groups of living beings. Many plants, especially amongst the lower forms, are capable of motion at some time or other during their life. As an example, if we examine rain water that has been standing for some days, we generally find minute green masses floating about in it. These on inspection under a microscope prove to be true plants (*Protococcus pluvi-
alis*), each being a little rounded mass containing green particles. After watching for some time, however, it will be seen that some of these plants change their form, becoming more pear-shaped, at the same time giving off two very minute threads or cilia. These are thrown into rapid motion, propelling the plant

through the water in which it floats. In this mode of motion the *Protococcus* cannot be distinguished from many of the low forms of animal life.

A better distinction is to be found in the food that is assimilated. Plants, like animals, require food ; but they, as a rule, possess the power of obtaining it from the mineral kingdom only, whilst animals require for their food either vegetable or animal substances. There are, however, exceptions to this rule, and, as we have said, the two kingdoms appear to merge gradually the one into the other in their lower forms.

Botany, then, being the science which treats of plants, has several branches. *Morphology* deals with the forms of the organs of plants. *Anatomy* treats of their internal structure ; and *Histology* of the minute appearance they present under the microscope. *Physiology* deals with the functions of the various organs, and the phenomena attendant upon life. *Classification* has to do with the grouping of plants according to their relation one to another. *Geographical Botany* deals with the distribution of plants ; and *Palæontological Botany* with the remains of plants which existed in former times.

CHAPTER II.

FLOWERING AND FLOWERLESS PLANTS—STRUCTURE OF THE SEED.

ALL the higher forms of plant life are distinguished as being able, at some time or other of their existence, to produce flowers.

It is this fact which causes the Vegetable Kingdom to be divided into the two subkingdoms of **Flowering Plants** or **Phanerogams**, and **Flowerless Plants** or **Cryptogams**.

In the present work we shall deal entirely with the Phanerogams.

The point in which all of these plants agree is that they spring originally from seeds. To understand a seed thoroughly, it is well to commence with a large specimen, as, for instance, a Broad Bean, Haricot, or a Pea.

If we examine a Broad Bean carefully, we notice that it has an elongated shape. At one end there is a scar or mark. This is the point at which the seed was attached to the fruit, and is known as the **hilum**. At one end of this there is a minute hole. This can be readily seen by allowing the bean to soak in hot water for a short time; then on taking it out and squeezing it, a drop of water is seen to escape through the aperture. This hole, which leads into the interior of the seed, is called the **micropyle**.

Next, taking a sharp penknife, we find that we can peel



FIG. 1. — Broad Bean. *A*, seed, with one cotyledon removed; *c*, remaining cotyledon; *kn*, the plumule; *w*, the radicle; *s*, the spermoderm. *B*, germinating seed: *s*, spermoderm, a portion torn away at *l*; *n*, hilum; *st*, petiole of one of the cotyledons; *k*, curved epicotyledonary portion of axis; *i*, *he*, short hypocotyledonary portion of axis; *h*, main root; *rus*, its apex; *kn*, bud in axil of one of the cotyledons. (After Sachs.)

the skin from off the seed, leaving a whitish fleshy mass within. This **skin** is called the **testa**.

The mass within the testa is called the **nucleus** of the seed. In the case of the Broad Bean, this nucleus is entirely made up of the young plant or **embryo**. At one end there is a pointed portion which is directed towards the micropyle. This is destined on germination to be prolonged to form the root, and is known as the **radicle** (fig. 1).

The great mass of the nucleus is made up of two fleshy lobes, which can easily be separated from one another—the **cotyledons**; and between these at the top of the radicle there is a little portion curved over and divided at the end in a plume-

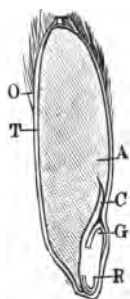


FIG. 2.—Longitudinal section of a seed of Oat: A, endosperm; C, the single cotyledon; G, plumule; R, radicle; T, testa; O, hairs.



FIG. 3.—Germination of the Oat: a, cotyledon; e, axis of the embryo; d, radicle; f, plumule.

like manner. This, which is known as the **plumule**, will, under favourable circumstances, grow into the stem and leaves of the future plant.

In some seeds, as, for instance, those of the grasses, there is in the nucleus a substance, **albumen**, in addition to the embryo of the plant (fig. 2). This albumen may originate from two different parts of the ovule, and hence is known either as **endosperm** or **perisperm**.

The term albumen is rather a misleading one, as it might lead the student to imagine that the substance contained within the seed is identical in chemical composition with animal albumen, such as is found in the white of an egg, whereas it differs in its characteristics in various plants. In cereals it is *mealy* or *farinaceous*; in the Heart's-ease it is *fleshy*; in the Poppy and Cocanut it is *oily*; in the Mallow, *mucilaginous*; in the Vegetable Ivory and Coffee, *horny*.

Seeds containing albumen are spoken of as **albuminous**, whilst those **destitute of it** are **exalbuminous**.

There is another point in which seeds differ. On examining a grain of Wheat, or of an allied cereal, we find that there is only one cotyledon present, instead of, as in the case of the Bean, two. Many plants resemble the Bean in having two cotyledons present in their embryos; whilst others, like Oats, have but one. This causes the division of the sub-kingdom of Flowering Plants into two groups: **Dicotyledons** include those **Phanerogams with two** (or in some Conifers more) **cotyledons**; whilst **Monocotyledons** are **those with only one**. As we proceed further we shall find that there are other differences between these two great classes.

CHAPTER III.

CELL STRUCTURE.

THE whole of the various organs of plants are made up of a large number of component parts—cells, so minute as a rule as to be invisible separately to the naked eye. If a little brewer's Yeast be examined under a hand magnifying-glass, it is seen to present a granular appearance. If it be more highly magnified, it is found to consist of a large number of minute rounded particles (fig. 4); these are separate cells. We recognize in them the outer pellicle or cell wall and the cell contents.



FIG. 4.—Beer Yeast (*Saccharomyces Cerevisiae*).

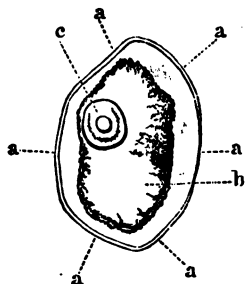


FIG. 5.—A cell from the root of an Orchid :
a, the cell wall, consisting of cellulose ;
b, the protoplasm, contracted by alcohol ;
c, the nucleus with a nucleolus.

The cell wall may be absent during a portion of the cell's existence ; it is simply inert, not-living matter ; but in the Vegetable Kingdom it is always sooner or later produced. The principal substance contained in it is **cellulose**, a compound of carbon, hydrogen, and oxygen, having the chemical composition $(C_6H_{10}O_5)_3$.

Cellulose is not coloured blue by means of iodine alone, although it is so changed by the action of iodine and sulphuric acid, thus being distinguishable from starch, which has the same percentage composition, but is turned blue by iodine.

Cellulose is insoluble in water, both cold and boiling; also in alcohol, ether, and dilute acids. It is found almost pure in Cotton wool, but generally the cell wall contains mineral matter and water in addition.

During the growth of the cell the cellulose is often converted into substances which are of an allied composition, but which differ from it in various physical and chemical properties.

The chief of these are—

1. **Suber, or Cuticularized Cellulose.**—This is highly elastic and almost impermeable to water; when treated with iodine or Schulze's solution it turns yellow; when warmed (not boiled) in concentrated solution of potash it is stained bright yellow. It is met with in Cork, epidermis cells, and pollen grains.

2. **Lignin.**—In this case the cell wall is hard, inelastic, and permeable to water. Treated with a solution of aniline sulphate acidulated with a few drops of sulphuric acid, it is stained yellow. It is met with in wood cells.

3. **Mucilage.**—When dry it is hard and horny, but it very readily absorbs water, swelling and becoming gelatinous. The reactions are the same as those of cellulose. Examples are to be found in the epidermis cells of the seeds of the Flax and Quince.

The cell contents are very various; we will note some of the principal:—

Protoplasm.—It is of this substance that the whole of the young cell is at first made up. It is very complex in its chemical constitution, but always contains nitrogen. Iodine colours it brown, and concentrated sulphuric acid rose-red; whilst it is also stained by magenta. It is soft and jelly-like in consistency, never truly fluid. At times it is homogeneous and transparent; more often it is granular. It forms the vital portion of the cell, and possesses considerable power of

movement. It readily absorbs water, which, however, forms drops or vacuoles in its interior.

In many cases the protoplasm contained within the cellulose wall shows a tendency to rotate or circulate in various directions through the cell, often carrying with it substances which may be embedded in it. This is especially well seen in the cells of many water-plants (see fig. 18).

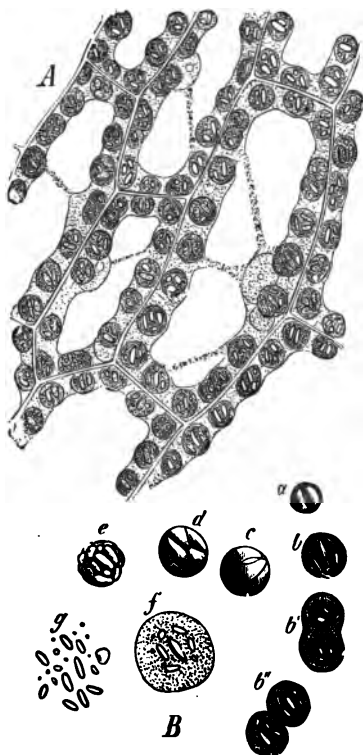


FIG. 6.—Chlorophyll granules in cells of leaf of *Funaria hygrometrica*, a moss. *A*, granules of chlorophyll, with contained starch-grains embedded in the protoplasm of the cells. *B*, separated chlorophyll granules containing starch: *a*, *b*, young granules; *b'*, *b''*, chlorophyll granules dividing; *c*, *d*, *e*, old chlorophyll granules; *f*, granule swollen up by action of water; *g*, starch granules remaining after chlorophyll destroyed by action of water. (After Sachs.)

Chlorophyll is the substance to whose presence the green colour of plants is due. It occurs (in the higher plants) in the form of granules imbedded in the protoplasm of various parts of the plant. These granules really consist of two parts—a colourless more or less solid portion, which is formed out of the protoplasm; and a green colouring matter diffused through and colouring it.

The colouring matter of the chlorophyll is soluble in alcohol, ether, chloroform, benzene, and essential oils and fats.

The chlorophyll granules are produced in the protoplasm under the influence of light, except in

the case of the germinating seeds of some Conifers and the fronds of Ferns.

If a growing plant be placed in perfect darkness no chlorophyll will be formed; the leaves and other organs which would naturally have a green colour present a pale and sickly appearance. Such organs are said to be *etiolated*. An example is to be found in the leaf-stalks of Celery and Rhubarb. In the natural state they are green, but when cultivated, earth is heaped up so as to remove them from the influence of the light. The result of this is to produce the white leaf-stalk of the edible varieties, this change of colour being accompanied by change of flavour.

Chlorophyll plays a most important part in the plant economy, which we shall notice when we treat later on of the food supply of the plant.

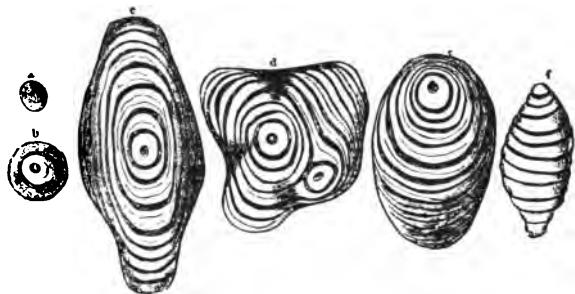


FIG. 7.—Various forms of starch-grain from the Potato.

Starch has the same percentage composition as cellulose, but differs from it in many of its properties. It is insoluble in cold water, but swells up very strongly on the addition of boiling water, forming a paste. It is readily turned a dark blue by the addition of iodine. As this blue colour, however, is destroyed by heat, the starch requires to be cold, or nearly so, for its production. Exposed to heat for some time, or to dilute sulphuric acid for a shorter period, starch is converted into dextrine or British gum, and finally into sugar.

Starch occurs in the plant in the form of granules varying in their size. Amongst the smaller are those of Rice starch, which are frequently under $\frac{1}{5000}$ of an inch in diameter, whilst those of a kind of Arrow-root are often as much as $\frac{1}{300}$ of an

inch in length. In external form they vary very much, but they usually present a central portion, the hilum, or nucleus,

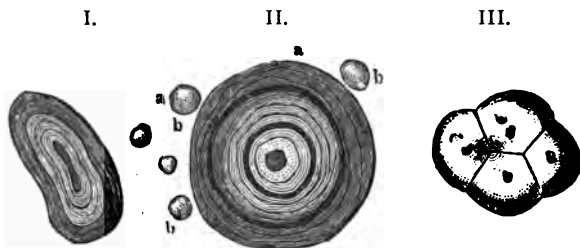


FIG. 8.—I. Starch-grain from the Scarlet Runner (*Phaseolus multiflorus*). II. *a, b*, Starch-grains from Rye. III. Starch-grain from the stem of the Sarsaparilla (*Smilax Sarsaparilla*).

round which the starch substance is arranged in concentric layers. Probably this striated appearance is due to a varying quantity of water in the different parts of the granule.

Starch, like chlorophyll, requires *light* for its formation. The granules are at first formed within those of the

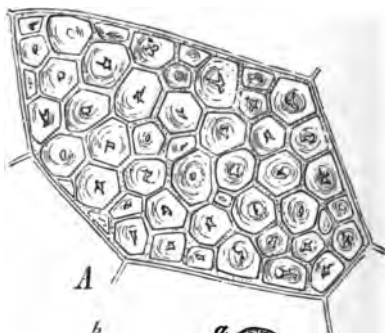


FIG. 9. — Starch-grains from the latex of *Euphorbia splendens*.



FIG. 10.—Cell of endosperm of *Zea Mays*, Maize. Thin plates of protoplasm separating the polygonal starch-grains. *a-e*, granules from germinating seed of Maize becoming dissolved and disintegrated. (After Sachs.)

chlorophyll; then in the dark they are converted into soluble substances which are transferred to other parts of the plant,

where they are again fixed as reserve food materials in the form of starch.

Cell Sap.—In the young cell the whole of the wall, with the protoplasm and other contents, is saturated with a watery fluid containing various mineral and other substances in solution.

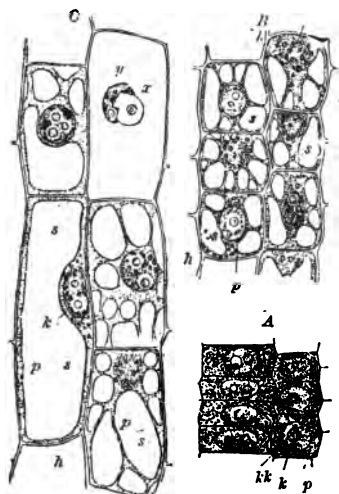


FIG. 11.—Cells from the root of *Fritillaria imperialis*. A, very young cell from near apex. B, from 2 mm. above the apex. C, from about 8 mm. above the apex: *h*, cell wall; *p*, protoplasm; *k*, nucleus; *kk*, nucleoli; *s*, vacuoles and cell-sap cavity. (After Sachs.)

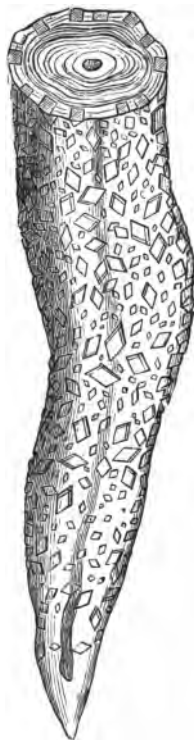


FIG. 12.—Crystals of calcium oxalate in the cell wall. *Welwitschia mirabilis*. (After Sachs.)

This constitutes the cell sap. As the cell increases in age this sap collects in drops (*vacuoli*), which gradually run together until the whole of the interior of the cell is filled with sap, presenting the appearance of being surrounded by two coats—viz. within, the layer of protoplasm; and without, the cell wall.

This sap is most important, as it contains much of the food material of the plant.

Crystals.—Very often some of the mineral substances contained in the sap become crystallized out, and make their appearance either within the cell or in the wall. In some plants the amount of these crystals is very great. In the Old-Man Cactus, as much as 80 per cent. of the dried tissue consists of them. Professor Bailey found in a square inch of Locust bark no thicker than writing-paper, as many as a million and a half of these crystals. The root of Turkey



FIG. 13.—Cell from the stem of *Aloë retusa*, with raphides.

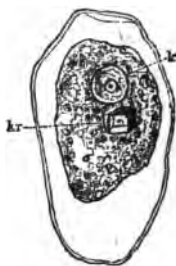


FIG. 14.—Crystalloid, *kr*, in a parenchymatous cell of the Potato tuber; *k*, nucleus.

Rhubarb contains so many as to give a gritty character to it when chewed. As a rule the crystals are found in cells where there are no other granular contents, but this is not universal. Mostly they consist of oxalate of calcium. Carbonate or sulphate of calcium is sometimes met with. In shape they are either cubical, octahedral, or needle-like (hence the name of *raphides*, from the Greek name for a needle).

Crystalloids.—In some cells, especially those of fatty seeds like the Brazil nut, bodies are found which are crystal-like in appearance, but, instead of being mineral in composition,

consist of proteinaceous or nitrogenous material closely allied to protoplasm. They are insoluble in water, but break up in a peculiar manner so as to appear to be composed of several layers.

Aleurone Grains are minute rounded grains found in the cells of many seeds just before ripening. They often contain crystalloids. They are soluble in caustic potash. They are often oily, and appear to be food materials stored by the plant.

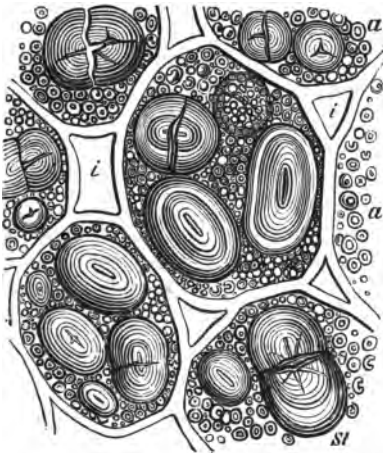


FIG. 15.—Cells of cotyledon of *Pisum sativum*, Pea. *St*, starch granules with central hilum and concentrated striæ; *a*, granules of aleurone; *i*, intercellular spaces. (After Sachs.)

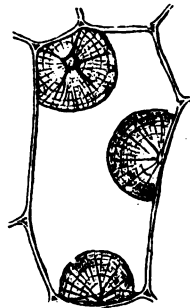


FIG. 16.—Sphere crystals of inuline in a parenchymatous cell from a tuber of the *Dahlia* preserved in alcohol, after addition of nitric acid.

Inuline is a peculiar substance found in the roots of Compositæ, e.g. *Dahlia* and *Othonna*, and now and then in stems. It is very closely related to starch and sugar, and in the living plant is only found in solution in the sap; but by the addition of alcohol or glycerine it separates out, either in a frothy condition or as beautiful spherical masses known as *sphere crystals* (fig. 16).

CHAPTER IV.

CELL GROWTH, SHAPE, FORMATION, AND TISSUES.

CELLS grow by the process of **intussusception**. This is a term which requires some amount of explanation. We must look upon the cell wall as consisting, not of a continuous homogeneous layer of cellulose, but of an immense number of isolated, minute, solid particles or molecules, which are, comparatively speaking, unalterable.

Between these it is supposed that water percolates so that each molecule is surrounded by a layer of liquid.

When fresh food material is brought to the cell, the new molecules are intercalated between those already existing there, and thus they cause an increase in the size of the cell wall.



FIG. 17.—Cells from the flesh of the Peach, spherical, ellipsoidal, and hour-glass-shaped.

Such a process of increase by means of intussusception is very characteristic of the growth of organic beings, and is totally different from the manner in which minerals increase in size. If a crystal, say of alum, be suspended in a vessel containing a strong solution of the same substance, it enlarges by a process of *accretion*—that is, a series of fresh layers form upon its exterior.

Growth by intussusception often produces a change in the shape of the cell. The normal form is more or less spherical; this, however, is rarely preserved except in the case of uni-



FIG. 18.—Circulation of protoplasm in an elongated cell: *k*, the nucleus with a nucleolus. The arrows indicate the direction of the currents.

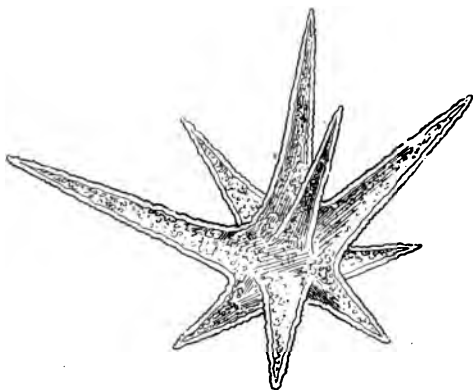


FIG. 19.—Star-shaped cell from stalk of Water-lily (*Nymphaea stellata*).

cellular plants. If the wall grows more vigorously at the two extremities than at the sides, the cell will become *oval* or *elliptical* (fig. 17), then *elongated* (fig. 18), and lastly *fusiform* or *spindle-shaped* (fig. 71, *t*).

On the other hand, if a very vigorous growth takes place at certain parts whilst the rest of the cell wall is but slightly developed, several protuberances will be produced upon the surface, and a *stellate* or *star-shaped* cell is formed (fig. 19).

Another cause modifying the shape of individual cells is to be found in their



FIG. 20.—Tabular cell from the epidermis of *Callitriche*.

mutual pressure the one upon the other during growth. By this means they may become flattened or tabular (fig. 20) or polyhedral (fig. 21).

Other forms of cells are shown in figs. 22, 23, and 24.

At first the cell wall appears as a thin layer of cellulose perfectly permeable to liquids. In some cells but little thickening

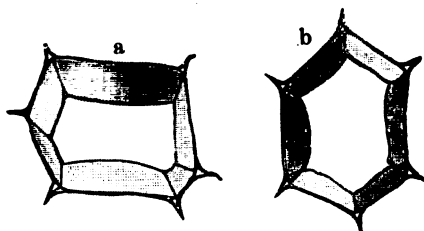


FIG. 21.—Polyhedral cell from the pith of *Acacia lophantha*: *a*, seen in transverse; *b*, in longitudinal section.

takes place during growth; in many others, however, very soon layers of secondary deposit are formed lining their interior surfaces. At first these layers are complete and continuous like the original coat, but soon they are developed but slightly or not at all at certain points, thus causing perforations in their substance. As the holes thus produced in the contiguous



FIG. 22.—Disc-shaped cell; a unicellular Alga, *Coccinodiscus*.



FIG. 23.—Tetrahedral cells; spore of a Fern in various positions.

layers correspond with one another, canals are gradually formed leading towards the centre of the cell cavity.

Such cells, when seen under a microscope, transmit the light differently through their pore canals and through the thickened walls, and hence they present a pitted or dotted appearance as though pierced by a number of holes (fig. 25). These cells are known as **pitted** or **dotted cells**.

In other cases the secondary deposit takes the form of a spiral band round the wall, thus producing a spiral cell



FIG. 24.—Branched bast-cell of the Larch.

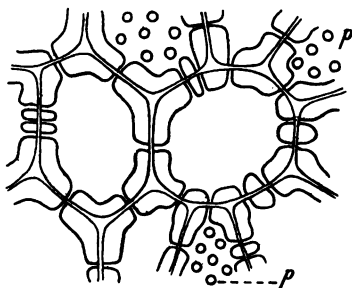


FIG. 25.—Section through endosperm of *Antholyza*. Parenchyma with thickened cell walls; *p*, pores seen from their end.

(fig. 28). Or else it is deposited as separate rings, when an annular cell is formed (fig. 29). When the thickening is

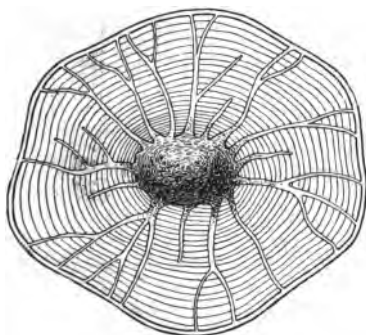


FIG. 26.—Stone cell from shell of Walnut (*sclerenchyma*).

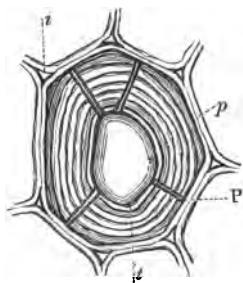


FIG. 27.—Transverse section of a cell of the pith of *Clematis*: *p*, primary cell wall; *t*, innermost thickening layer; *P*, pore canal; *i*, intercellular space.

arranged in an irregular manner, producing a perfect network over the wall, the cell is said to be **reticulated**.

Verv often there is in the cell a gradual passage from a

spiral to an annular or reticulated marking (fig. 31). At other times there is a spiral or reticulate marking in addition to the pits or dots. Such cells as these are known as *tracheïdes* (fig. 32).



FIG. 28.—A spiral cell from *Opuntia Tuna* (Prickly pear), with strongly thickened spiral band.

Fig. 33 shows another form of thickening, known as *scalariform*, or ladder-like. In this case the secondary deposit is arranged in transverse layers like the rungs of a ladder. Such cells are well seen in the stems of Ferns.

A very important form of pitted cell is met with, especially in the wood of the Fir trees and their allies. In these cases the pit is *funnel-shaped*, being wide on the outside and gradually tapering till it forms a tube or pore canal leading into the centre of the cell.

On examining these cells by means of a microscope, they present the appearance of a central pit surrounded by a border, and they are called *cells with bordered pits*. This appearance



FIG. 29.—Annular cell from *Arundo donax*, with strongly thickened rings placed at different distances and different angles.

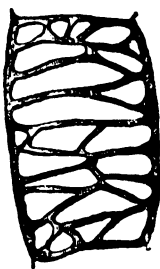


FIG. 30.—Reticulately thickened cell of the Touch-me-not (*Impatiens noli-me-tangere*).



FIG. 31.—Annular cell from an *Opuntia* with rings passing over into a spiral band.

is caused by a varying amount of light being transmitted through the central pore which forms the pit, and the funnel-shaped upper portion which forms the border.

Very often the cell wall between the two "borders" becomes

absorbed, in which case a complete passage is made between the two cells.

Besides these appearances due to secondary deposit, there is, especially in older cells, a striation or stratification of the cell wall, which appears to be due to the varying amount of water in the different parts of the wall.



FIG. 32.—Piece of a reticulately pitted tracheide from the Linne (*Tilia grandifolia*).



FIG. 33.—Scalariform cell from the underground stem of the Brake (*Pteris aquilina*).

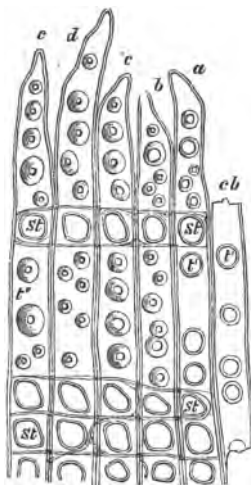


FIG. 34.—Longitudinal section of wood of *Pinus sylvestris*. Bordered pits, p p' p'' , increasing in age; a — e , wood cells, e , eldest, a , youngest; cb , wood cells of cambium; st , large pits, where medullary rays touch wood cells. (After Sachs.)

Another important change in the history of the cell is the formation of *vessels*, or cell fusion.

Vessels are formed by the union of several cells (vascular cells), the walls between them being either partially or entirely absorbed.

When several cells standing one over another have the walls separating them simply perforated in a sieve-like manner,

sieve-tubes or **bast-vessels** are formed. These are found in various parts of plants, and contain nutritive materials necessary for the nourishment of the plant. When the disappearance of

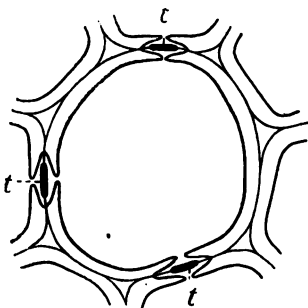


FIG. 35.—Transverse section through tracheide of wood of *Pinus*, showing three bordered pits with their torus (*t*) in the centre.

the separating walls is more complete, so that the cells form more or less long tubes, true vessels are produced, and these are known, according to the nature of their component cells, as pitted, spiral, annular, reticulate, or scalariform vessels.

These true vessels usually possess a considerable quantity of secondary deposit, and are seldom branched. As a rule they are partly filled with sap which is supplied to the transpiring leaves, but in the early spring, when the amount of sap which rises is very large, the vessels are often filled completely.

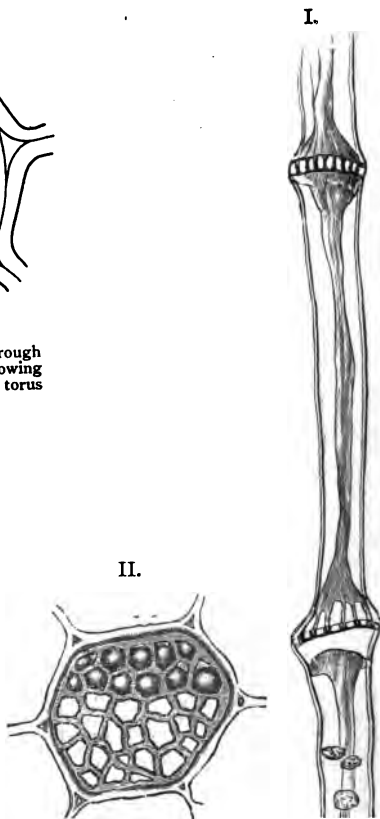


FIG. 36.—I. Sieve tube from the White Bryony (*Bryonia dioica*), the horizontal partition walls with peculiar thickenings. II. Transverse section of a sieve-disc, the upper part represented with the thickening substance, which takes the form of wart-like elevations; the lower part without it.

Bast tubes or bast fibres are generally more pointed and sometimes branching (fig. 24). The coalescence between the component parts is so complete that the separate cells cannot be distinguished when the fibres are examined by means of the microscope. Bast fibres do not often communicate directly with one another; when they do so it is by means of their lateral branches.

Very closely related to the sieve-tubes mentioned above,

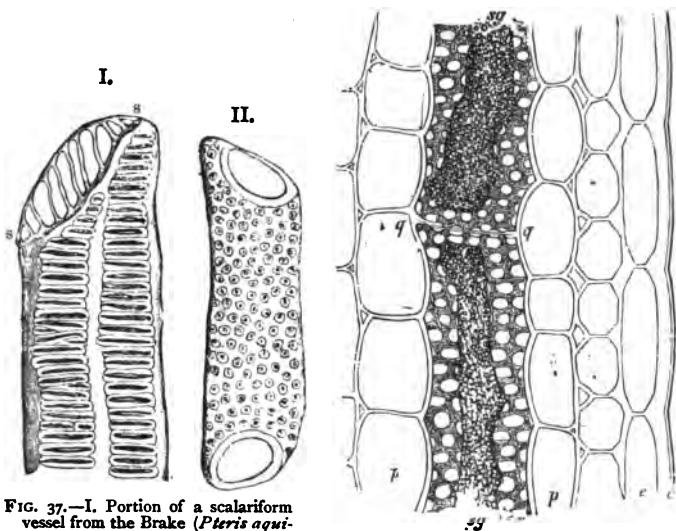


FIG. 37.—I. Portion of a scalariform vessel from the Brake (*Pteris aquilina*): *s, s*, the transverse division wall broken through in a reticulate manner. II. Pitted vascular cell from the stem of a Grass (*Phragmites communis*), with numerous small bordered pits.

FIG. 38.—Vesicular vessel in longitudinal section of scale of bulb of Onion (*Allium Cepa*): *e*, epidermis with cuticle (*c*); *p*, parenchyma; *sg*, coagulated contents contracted to show the porous walls. (After Sachs.)

especially in containing like them nutrient fluids, are **vesicular vessels** and **laticiferous vessels**. The former consist of elongated cells containing a milky juice and bundles of needle-shaped crystals.

Laticiferous vessels are tubes more or less branching, often forming a complete network, and containing a fluid known as *latex*, which is often milky, sometimes coloured, and varies in its composition in different plants.

Cells do not grow indefinitely ; the size of the adult cell varies. **Prosenchymatous cells** vary from $\frac{1}{40}$ to $\frac{1}{12}$ of an inch in length, and from $\frac{1}{1500}$ to $\frac{1}{3000}$ of an inch in diameter. **Parenchymatous cells** vary as a rule from $\frac{1}{250}$ to $\frac{1}{1200}$ of an inch in diameter, whilst some in the pith of plants, in succulent parts, and in water-plants, are as much as $\frac{1}{80}$ or even $\frac{1}{30}$ of an inch in diameter.

As the plant increases in size, fresh cells are produced, being formed out of those already existing. This process is known as **cell formation**. There are several modes by which this takes place, but in the formation of the vegetative cells of

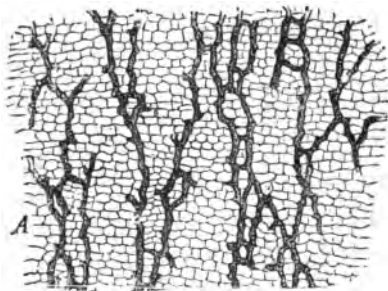


FIG. 39.—Transverse section of phloëm of root of *Scorzonera hispanica*, showing branching and anastomosing laticiferous vessels.

higher plants it is always by means of **cell division**. Vitally active cells always contain a portion of the protoplasm more or less distinctly separated from the general mass, known as the nucleus, and which often contains small granules or nucleoli. When cell division is about to take place, two nuclei are formed either by the division of the original one, or by its disappearance, and the formation of two fresh ones.

The whole mass of the protoplasm now aggregates around these nuclei, and a cell wall is formed between the masses thus produced, growing inwards from the circumference to the centre, thus dividing the mother cell into two daughter cells, each of which may grow to the size of the mother cell, and itself undergo division. The formation of reproductive cells we shall have to notice later on (p. 96).

Except in a few cases, cells do not remain through life individually separate, but are united together to form "tissues." These may be grouped according to either their *function* or their *structure*. Under the former method of division we have two kinds, viz. **meristem**, which is a tissue where the cells remain vitally active and capable of division; and **permanent tissue**, where the cells are no longer able to divide. If we arrange them according to their structure, we distinguish those tissues which consist of elongated cells overlapping one another, and which are known as **prosenchyma**, and those which are formed of shorter cells placed end to end, or **parenchyma**. These two forms of tissues, however, pass the one into the other by endless gradations.

Sometimes the term **sclerenchyma** is used to denote either prosenchymatous or parenchymatous tissues, where the walls of the cells have become very thick and hard, and often dark coloured (fig. 26).

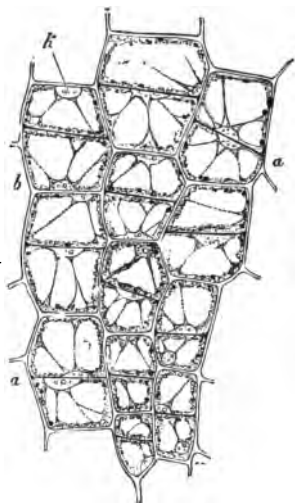


FIG. 40.—Cells of stem of *Vicia faba*. Meristem cells in process of division: *k*, nucleus; dividing, *a*; fully divided, *b*. (After Prantl.)

CHAPTER V.

GERMINATION, ROOT GROWTH, STRUCTURE, AND FUNCTIONS.

IF a living seed be placed in the soil and be supplied with moisture and warmth, and exposed to fresh air, germination will ensue. The range of temperature between which this is

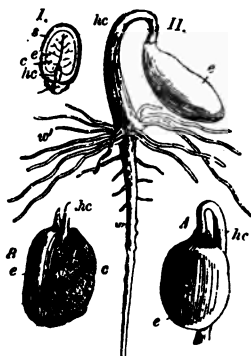


FIG. 41.—*Ricinus communis*. I. Longitudinal section of ripe seed. II. Germinating seed, the cotyledons still within the testa, shown more distinctly in A and B: *s*, testa; *e*, endosperm; *c*, cotyledon; *hc*, hypocotyledonary portion of axis; *w*, primary root; *w'*, lateral rootlets; *x*, the caruncle (or aril), a peculiar appendage to the seeds of *Euphorbiaceae*. (After Sachs.)



FIG. 42.—Germinating seed of cabbage: *b*, axis; *c*, *d*, the two cotyledons, which have risen above the soil, the testa *a* not being yet completely thrown off.

possible varies with different plants, but it may be stated generally as being between 5° or 6° C. and 40° C.

Either the roots at once lengthen and grow out through the micropyle, or, which is more often the case, the lower part of the cotyledon, known as the *hypocotyledonary* portion of the stem, becomes elongated, pushing the end of the root before it out of the seed.

If we sow in some soil specimens of the following seeds : Broad Bean, Acorn, Cress, Cabbage, Castor Oil, Pine, Date, and Wheat—and watch the germination as it takes place, we

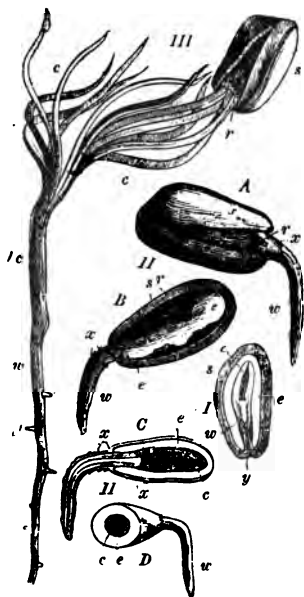


FIG. 43.—Seeds of *Pinus Pinea* in different stages of germination. *I*. Ripe seed in longitudinal section: *s*, testa; *e*, endosperm; *w*, radicle of embryo; *c*, the cotyledons; *y*, the mircopyle end of seed, with the rootlet directed towards it. *II*. Germination commencing: *A*, Testa, *s*, ruptured, and rootlet, *w*, protruding; *r*, red membrane inside testa; *x*, ruptured embryo sac: *B*, portion of testa removed; *e*, endosperm: *C*, longitudinal section; *c*, cotyledons: *D*, transverse section. *III*. Germination complete, the cotyledons, *c*, unfolding, and the hypocotyledonary part of stem, *hc*, elongated, the main root, *w*, developing lateral rootlets, *w'*. (After Sachs.)

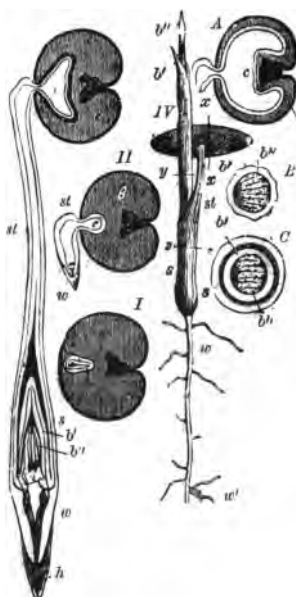


FIG. 44.—Germination of *Phoenix dactylifera*. *I*. Transverse section of seed before germination. *II*. *III*. *IV*. Different stages of germination. *A*, Transverse section of seed at *x*, *x*, in *IV*.; *B*, at *x*, *y*; *C*, at *s*, *s*. The following letters refer to all the figures: *e*, endosperm; *s*, sheath of cotyledon; *st*, its stalk; *c*, apex, forming an organ of absorption by which the endosperm is entirely removed, the growing end occupying the place of the absorbed endosperm; *w*, primary root; *w'*, secondary root; *b*, *b'*, leaves succeeding the cotyledon; *b''*, the first foliage leaf; *h*, pileorhiza. In *B*, *C*, the folded lamina is seen cut across. (After Sachs.)

shall find that there is a great difference with regard to the growth and development of the cotyledon during the process.

In *exalbuminous* seeds, where the cotyledons are thick and

fleshy, as in the Bean (fig. 1) and Acorn, they remain within the seed during germination, finally perishing after the food-material contained in them has been used up for the growth of the embryo. In the case of the Cress and Cabbage we have an *exalbuminous* seed where the cotyledons are thin, and here they rise out of the soil to form the first leaves, carrying the testa with them (fig. 42). The Castor-oil plant has an *albuminous* seed; in this case the cotyledons are not liberated until

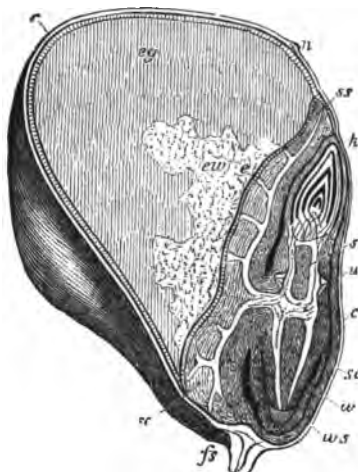


FIG. 45.—Longitudinal section of fruit of *Zea Mais*. *c*, Pericarp; *s*, remains of the stigma; *fs*, base of the fruit; *eg*, hard yellowish part of endosperm; *ew*, white softer portion of endosperm; *sc*, scutellum (cotyledon) of embryo; *ss*, its apex; *e*, its epidermis; *k*, plumule; *w* (below), the main root; *ws*, sheath covering main root; *w* (above), lateral rootlets springing from the first internode of the stem, *st*. (After Sachs.)

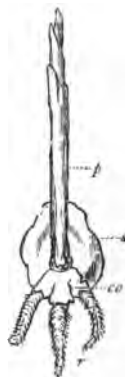


FIG. 46.—Germinating embryo of Oat (the endosperm removed). *p*, The plumule; *s*, the scutellum; *r, r*, the rootlets; *co*, the coleorrhiza.

after the *endosperm* has been all absorbed (fig. 41). In the case of the Pine we have an analogous growth (fig. 43), the cotyledons (which are numerous) appearing above ground after the absorption of the albumen, the peculiarity here being the development of *chlorophyll* in the cotyledons before they rise above the surface. All these are *dicotyledonous* seeds. The remaining two illustrate the germination of *monocotyledons*. In

the Date Palm (fig. 44) the lower part of the cotyledon lengthens, pushing the roots and plumule out of the seed, whilst the rest of it remains in contact with the albumen absorbing it.

In the Wheat (fig. 45) the cotyledon is developed to form a plate where it is in contact with the endosperm, and is known

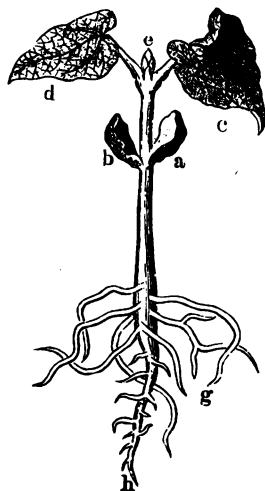


FIG. 47.—Germinating Bean: *a, b*, cotyledons; *c, d*, leaves; *e*, terminal bud; *h*, primary root; *g*, lateral roots.

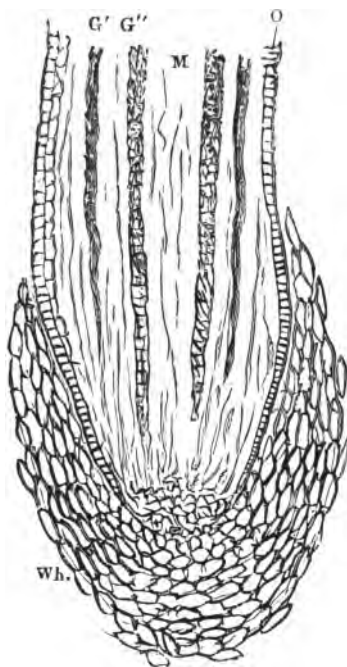


FIG. 48.—Longitudinal section through the apex of a root of *Aspidistra elatior*: *wh*, root-cap; *M*, pith; *O*, epidermis; *G'*, narrow spiral vessels; *G''*, broad reticulate vessels.

as the *scutellum*. This serves the purpose of absorbing the albumen.

When the cotyledons remain beneath the soil they are said to be *hypogeal*, *e.g.* Pea or Acorn; when they rise above, *epigeal*, *e.g.* Bean or Pumpkin.

There is also a great difference between Dicotyledons and

Monocotyledons with regard to the formation of the young root. In **Dicotyledons** the radicle is directly prolonged, and no branching takes place until after the young root has left the seed (fig. 47), so that the first root is a direct prolongation of the radicle, and is known as a *normal* root or tap-root. Such a mode of root development is called **exorhizal**. In **Monocotyledons**, on the other hand, there is a branching within the seed (fig. 46), and the radicle is not directly produced. Such roots are known as **adventitious**, or secondary, and the growth is said to be **endorhizal**.

The term "adventitious" is applied to all roots which are not developed by the direct growth of the radicle, hence also to all those developed from a stem, *e.g.* from runners or cuttings, or from leaves, *e.g.* *Begonia*.

ROOT STRUCTURE.

Even whilst the radicle is within the seed a change of shape and condition has come over some of the cells, which, however, is more apparent after the young root has commenced to grow (fig. 48). The outer layer of cells becomes more or less flattened, forming a complete protective coat known as the **epidermis**. At the extremity the cells are thickened in such a manner as to produce what is known as the root-cap or **pileorhiza**, which is intended to protect the growing extremity of the root during its prolongation. Just behind the root-cap there is a mass of meristem tissue, which forms the growing point of the root. This by the constant subdivision of its cells produces on its outer sides additions to the root-cap, thus making up for portions that have become worn off by the growth of the root, whilst on its inner side it forms fresh tissue, thus causing the root to increase in length. Roots, then, increase in length only by growth near the apex. The upper part of the root is made up of permanent tissue, consisting principally of a mass of parenchymatous cells forming the ground tissue, and in this there are developed, more or less completely, bundles of pro-senchymatous cells and vessels, forming what are known as fibro-vascular bundles, running from the base of the root towards the apex.

These bundles consist of xylem and phloëm, very similar to that which exists in the stem (see Chapter VI.). Each bundle contains prosenchymatous cells or fibres, vessels and parenchyma, but they differ from the bundles of the stem and leaves, in that the vessels are, as a rule, first formed near the circumference of the bundle, and the xylem and phloëm masses (which vary in number in different plants) alternate instead of

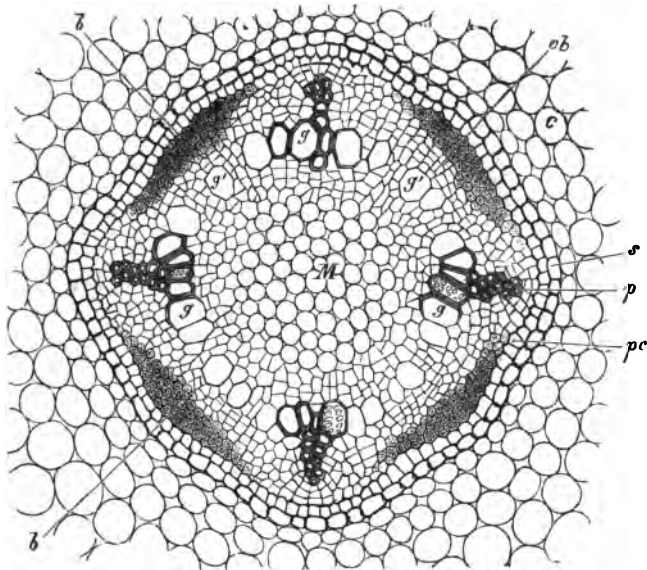


FIG. 49.—Transverse section of root of *Phaseolus*. *m*, Pith; *s*, endodermis or sheath of fibro-vascular bundles, with parenchyma of the ground tissue externally; *pc*, pericambium layer; *b*, primary phloëm of bast fibres; *g*, primary xylem, with vessels; *c*, cambium. (After Sachs.)

being placed the one outside the other. The bundles thus form an irregular star of three, four, or six rays.

In Dicotyledons there is, as a rule, a small number of such bundles, whilst in the roots of Monocotyledons the number is considerably larger.

Surrounding the bundles there is a ring of specially modified meristem cells known as the **pericambium**, and outside this an enveloping layer of cells forming the bundle-sheath or

endodermis. Branches of the root are formed by outgrowths of the pericambium which push their way through the adjacent tissue, and thus form rootlets, which repeat the structure of the original root (fig. 50).

Roots increase in thickness by the formation of a ring of meristem between the xylem and phloëm bundles, and which, by the repeated division of its cells, produces new xylem and phloëm.

The cells of the epidermis often possess prolongations or

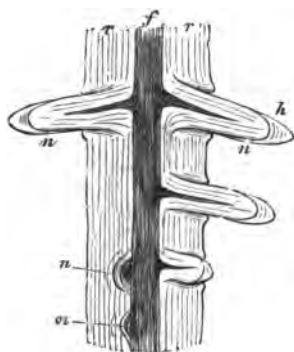


FIG. 50.—Longitudinal section of main root of *Vicia Faba*. *r*, *r*, Cortex of main root; *f*, fibro-vascular bundles; *n*, *n*, lateral rootlets developing from pericambium, and breaking through cortical tissue; *h*, pileorhiza of side rootlets. (After Prantl.)

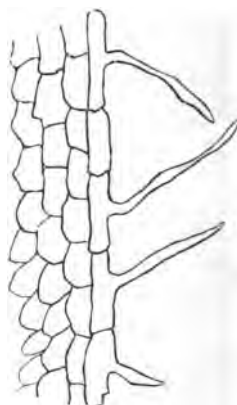


FIG. 51.—Epidermis of root with hairs.

hairs (*trichomes*), which tend to increase the amount of surface in contact with the soil (fig. 51).

FORMS OF ROOTS.

There are certain terms which are used in the description of the form of the root. When it is broad at its base and tapers towards the apex, as in the Carrot (fig. 52), it is **conical**. When it is broadest in the centre and tapers towards the two ends, as in the Radish (fig. 53), it is **fusiform**, or spindle-shaped. When it has become somewhat globular with a tapering extremity, as in the Turnip, or some varieties of Radish (fig. 54), it is said to be **napiform**; whilst the term

placentiform is applied to it if the tapering apex be absent, as in *Bulbine* (fig. 57). If a number of slender branches be given off, as in the Grass (fig. 55), the root is **fibrous**. When some



FIG. 52.
Conical root
of the Carrot.



FIG. 53.
Fusiform root
of the Radish.



FIG. 54.
Napiform root of
the Radish.



FIG. 55.
Fibrous root of
a Grass.

of these fibres become swollen in an egg-shaped manner, as in many Orchids (fig. 56), the term **tuberous** is employed.

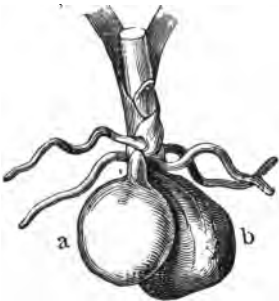


FIG. 56.—Tuberous root of an
Orchid.



FIG. 57.—Placentiform root of *Bulbine
pugioformis*.

The term **fasciculated**, or tufted, is used where there are a number of tubercles or fleshy branches arranged in a bunch, as in the *Anthericum* (fig. 58), or *Dahlia* (fig. 59).

When the fibres are enlarged only at their extremities, as in some *Asparagus* (fig. 60), the root is **nodulose**, or knotted; whilst if there be several swellings arranged like beads on a necklace, as in *Pelargonium triste*, it is said to be **moniliform**, or necklace-shaped.

ROOT FUNCTIONS.

1. The root is a great **organ of support**, tending to hold the plant fixed in the soil or other situation in which it may be growing.



FIG. 58.—Fascicled fleshy roots of *Anthurium muricatum*.



FIG. 59.—Tuberous fasciculated root of the *Dahlia*.

2. It is an **organ for the absorption of food**.

This raises three questions, viz. the source of the food, the nature of the food, and the manner of its introduction into the plant.

A. *The source of the food*.—The roots, as a rule, enter the ground, and hence receive the plant-nourishment from that source. In the case of some aerial plants, e.g. epiphytic Orchids (fig. 121), the roots absorb the food with the moisture present in the air; whilst in the case of many parasites, as the Mistletoe (fig. 61), the sucking roots penetrate into the stem of the plant upon which it grows, thus obtaining their nourishment second-hand.

B. *Nature of the food.*—A chemical analysis of the substance of a plant shows it to be composed of the following elements :—

Carbon, C.	Phosphorus, P.	Potassium, K.
Hydrogen, H.	(Silicon, Si.)	Calcium, Ca.
Oxygen, O.	(Chlorine, Cl.)	Magnesium, Mg.
Nitrogen, N.		Iron, Fe.
Sulphur, S.		(Sodium, Na.)

The five placed in the first column are sometimes called the organic elements, as they are required for the building up of the protoplasm and cellulose. Those placed in brackets are not so necessary or so universally met with as the rest.



FIG. 60.—*Asparagus undulatus*. Rhizome with nodulose roots.

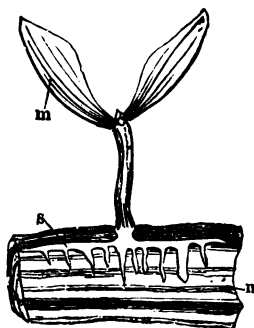


FIG. 61.—*n*, A piece of branch of an Apple tree cut through lengthwise, into which a young Mistletoe plant, *m*, has driven its sucking roots, *s*.

Since, then, the plant body is built up of these elements, it is evident that they must enter into the composition of its

food. They are not, however, absorbed in their elementary condition, being obtained from various compounds which contain them.

Carbon is obtained by green plants from carbon dioxide, also known as carbonic acid gas, CO_2 , a gaseous compound of carbon and oxygen, through the pores of the leaves. Carbon is one of the most important substances present, building up portions of all the plant-tissues, and usually forming one-half of the dried plant by weight.

Hydrogen, another element present in every organic compound, is obtained from water, H_2O , which is taken up in large quantities by the roots.

Oxygen.—The sources of this element are to some extent the two compounds H_2O and CO_2 already noted, and also the various **oxygen salts** of the metals, such as sulphates, phosphates, nitrates, etc. Besides this, the free oxygen of the atmosphere enters the plant, acting on the tissues, as we shall have to notice further on under the head of Respiration.

Nitrogen, which is an essential element of protoplasm, the albuminoids, and allied bodies, is obtained from ammonia, NH_3 , and compounds of nitric acid, HNO_3 , called nitrates. It must be borne in mind that, although nitrogen exists to a very large extent in the air in a free or uncombined state, most plants are only able to absorb it from its compounds (compare p. 76).

Sulphur is taken up as **sulphates**, that is, salts of sulphuric acid, H_2SO_4 ; probably chiefly calcium sulphate or gypsum, CaSO_4 . This element also is required for the protoplasm and albuminoids.

Phosphorus is obtained from **phosphates**, principally calcium phosphate, $\text{Ca}_3,2\text{PO}_4$.

Silicon is taken in as **silica**, SiO_2 , which is largely present in the soil; whilst the sources of **chlorine** are the **chlorides** of the various metals, especially of sodium, the chloride of which is common salt. The metals mentioned above are all obtained as salts combined with the acids we have noticed.

c. Method of introduction of the food substances into the plant.—Before any food can be absorbed it is necessary for it

to be in a state of solution. The water present in the soil dissolves the various food materials, and thus brings them into a fit state to be taken.

The outside surface of the root is entire, not perforated by holes, hence the solution of food has to be absorbed into the cells of the plant itself. This is accomplished by means of the process of *osmosis*. If two liquids be separated by a membrane permeable to both, they will flow through it and intermingle.

This can be very easily demonstrated by means of a simple experiment. If a vessel is closed below by a piece of bladder, whilst a tube is tightly fastened in the neck (fig. 62), and if a concentrated solution of cupric sulphate is placed in the vessel so that it stands a short way up the tube, and then the whole apparatus is plunged into a vessel of water as shown in the diagram, the two liquids will interchange, some of the cupric sulphate passing through the bladder into the outer water, whilst some of the latter enters the vessel. The two liquids do not, however, flow with equal rapidity. The law in all such cases is that the denser liquid flows more slowly than the less concentrated. As cupric sulphate solution is denser than water, a larger amount of the latter passes through the membrane than of the former, and therefore the liquid will rise in the glass tube. The passage inwards is called *endosmose*, whilst that outwards is termed *exosmose*. Sugar syrup may be used in the above experiment instead of cupric sulphate.

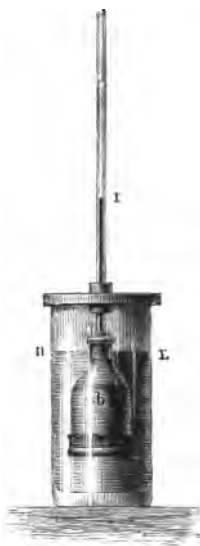


FIG. 62.—Apparatus for measuring osmose: *b*, a vessel filled with cupric sulphate closed below by a permeable membrane, and placed in a vessel of water. As the water passes through the bladder to mingle with the cupric sulphate, the level of the fluid will rise in the tube *r* in connection with the vessel *b*, but will fall at *n* in the outer vessel.

Let us apply this process to the root. Within the cells there is the sap, without there is the water with mineral salts in solution; we have here two liquids of different densities

separated by a permeable membrane, the cell wall. As a consequence osmosis ensues, some of the external water passing into the cell, and some of the sap being excreted into the soil. As, however, the sap is much denser than the water without, the flow of this latter is more rapid. By the same means the food material thus absorbed is transferred up the root from cell to cell towards the stem. The sap is densest in the upper cells, owing to the evaporation which is going on, and hence the flow is maintained. This passage of food takes place especially by means of the prosenchymatous cells or fibres, whilst absorption goes on most actively in those cells which are near the growing point and by means of the hairs.

The various food materials are not, however, taken up indiscriminately by the plants. It is found, if plants are grown in water containing equal amounts of the salts necessary for food, that the quantities removed are very different.

There is what is known as *selective power*, each plant removing from the soil those substances which are more especially necessary for its life, leaving other foods behind. Thus leguminous plants remove more lime than others; potatoes and tobacco more potash; cereals and grasses more silica; sugar-cane more nitrogen; and so on.

If the same plant be grown year after year in the same soil it gradually impoverishes the ground, whilst food materials needful for other plants will be accumulated. Hence is brought about what is known as rotation of crops—that is, growing a well-chosen selection of plants in succeeding years in the same soil, while at the same time various manures are employed to supply the place of the different materials removed from the soil.

3. The root is also, as we have seen, an **organ of excretion**; some of the sap, by osmosis, passes out into the soil, whilst the food enters the root. This is most important, as the sap is found to possess, as a rule, an acid reaction (it turns blue litmus red), and hence it aids the root by dissolving some of the materials present in the soil. Many of these substances, which are very needful for the food of the plant, are insoluble in water, but the acid sap dissolves them readily.

This can be easily shown by means of an experiment. Take a piece of perfectly smooth marble, and cover it with sand to the depth of about a quarter of an inch; sow in this some seeds of mustard or cress, and place in a position favourable for germination. When the young plants have grown for a short time, clear the whole off, and it will be found that the rootlets will have eaten their way into the marble, dissolving the substance, and forming minute grooves where they had been.

This explains how it is that we sometimes see large trees with their roots sunk into the solid rock. They have sprung up in that position from seeds, and as the roots have grown the acid sap has gradually eaten a passage for them until they have attained their present firm condition. Added to this, the root exerts a mechanical force, splitting the rock in the direction of pre-existing grooves, and thus helping to form a passage for their growth.

4. The preceding functions belong more or less to all roots; there is, however, a fourth, which is only occasionally seen. In some cases the root acts as a **storehouse of food**.

Let us take the case of a biennial plant, such as a Turnip. During the first year there are no flowers, but plenty of leaves. Food materials are absorbed and converted by means of the leaves into starch and other substances, which are stored up in the root, which latter becomes swollen. The next year the plant flowers and fruits, and this reserve of food is used up during the process, so that by the end of the second year the root has become shrivelled and fibrous.

5. The aërial rootlets of the Ivy are organs for support, and do not absorb any food.

CHAPTER VI.

DEVELOPMENT OF THE PLUMULE—FORMATION, STRUCTURE, AND FUNCTIONS OF THE STEM.

WHILST the radicle grows downwards to form the root of the plant, the plumule is elevated above the soil, and produces the stem, bearing leaves and other appendages.

Popularly the **stem** is looked upon as differing from the root in growing above the ground, but botanically there is a wider difference. Underground portions of many plants, as the Onion and Potato, which are generally called roots, are in reality stems.

The characters of stems as distinguished from roots are as follows :—

1. Their **growing points** are not covered with a root-cap, but are **surrounded by young leaves** (buds).
2. They have developed upon them **appendages**, variously modified, but which differ in structure from the stems themselves ; whilst roots simply branch, the branches being repetitions of the structure of the original root.
3. Whilst, as we have seen, the branches of the root have their origin in the deep-seated layers of the pericambium (endogenous growth), the **branches** and appendages of stems take their rise from more superficial layers (**exogenous growth**).

If we make a transverse section across the young stem during the first year of its growth, we find that there is a great difference in the appearance it presents in the two great groups of Dicotyledons and Monocotyledons.

Fig. 63 shows the section of a portion of a young dicotyledonous stem. On the exterior there is an **epidermis** of flattened cells.

At first this is like the epidermis of the root, consisting of a number of similar cells, always completely in contact; but after a while some of these become separated from one another, leaving an opening or **stoma** (plural, *stomata*) between them (fig. 64).

These stomata are always surrounded by two or four cells, which are generally smaller than the epidermal cells, are

I.

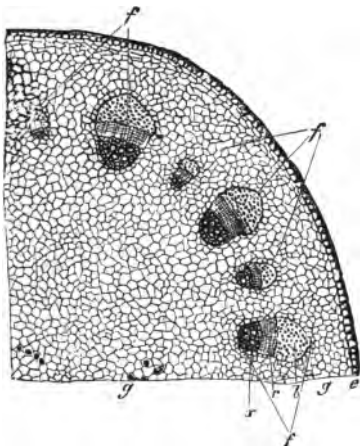


FIG. 63.—Transverse section of petiole of *Hel-leborus*, showing the three systems of tissues: *e*, epidermal; *f*, fibro-vascular; *x*, xylem; *c*, *b*, phloem—*c*, soft bast; *b*, bast-fibres; *g*, ground or fundamental tissue. (After Prantl.)

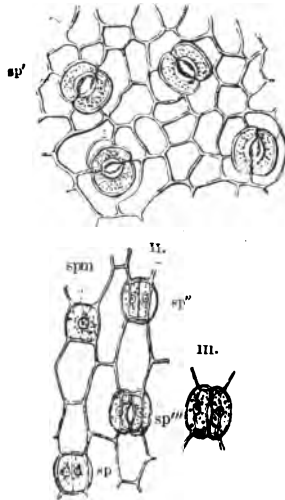


FIG. 64.—I. Horizontal section through the epidermis of the under side of the leaf of *Euonymus japonicus* looked at from below: *sp*, stomata. II. Course of development of the stoma of *Arthropodium cirrhatum*: *spm*, mother-cell ready for division; *sp'*, *sp''*, *sp'''*, successive stages of division. III. Mature stoma.

crescent-shaped, and contain chlorophyll. These are known as *stomatal* or *guard cells*.

More towards the interior of the stem there are developed some **bundles of cells** (fig. 63). At first these bundles consist of meristem tissue, known as **procambium**, forming a string of similar and growing cells. Very soon, however, the greater part of this passes into the form of permanent tissue, which

is separated into an outer or **phloëm** and an inner or **xylem** portion, leaving a band of meristem (**cambium**) between them (fig. 65).

The bundles, which now consist of fibres and vessels, with a few parenchymatous cells, are spoken of as **fibro-vascular bundles**. In many cases the fibres and vessels become very much hardened by the thickening of the secondary deposit, and the fibro-vascular bundles can then be easily separated from the surrounding portions of the stem. In other cases there is very little hardening in the bundles, and they cannot be thus separated.

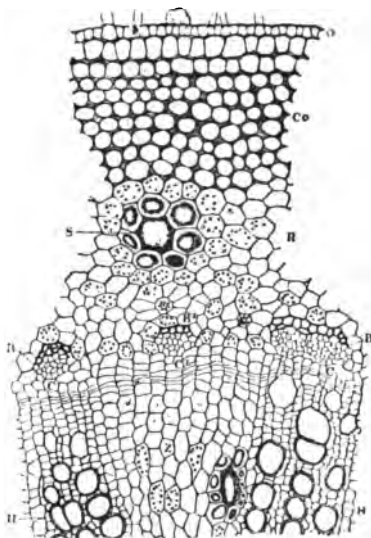


FIG. 65.—Transverse section through a young internode of *Bahmeria argentea*: o, epidermis; co, outer cortex (collenchyma); r, inner cortex; s, intercellular space; c, cambium of the vascular bundle; c', cambium of the thickening ring; b, bast portion; h, xylem portion of the vascular bundle; b', the bast formed from the intermediate cambium; z, medullary ray.

The rest of the stem in its young state is made up of parenchymatous cells, forming what is known as **fundamental** or **ground tissue**, which is divided into three parts—a portion in the centre of the stem, the **pith** or **medulla**; a ring underlying the epidermis, from which the **bark** is developed; and, lastly,

masses of cells which separate the fibro-vascular bundles and unite these two portions, the **medullary rays**.

The next change is in the cells which lie between the fibro-vascular bundles and the epidermis. Here are produced flattened cells filled with air, possessing flexible and elastic walls forming a close tissue without interspaces. These are **cork cells**. They are rarely (as in the Willow) developed from the epidermis itself; sometimes (as in the Poplar) from the

cells immediately beneath it, more often from the more deeply lying cells.

On the inner side there is developed a ring of meristem, known as **phellogen**, or cork cambium, whilst within this there is a layer of cells containing chlorophyll, the **phelloderma**, or green layer. Sooner or later all the cells outside the cork tissue dry up and shrivel, forming the outermost layer of the bark.

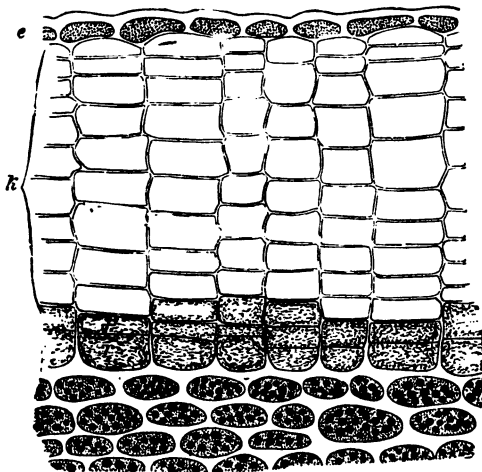


FIG. 66.—Transverse section of one-year-old stem of *Ailanthus glandulosus* : *e*, epidermis withered ; *k*, cork cells, formed by the inner cells with protoplasm, the cork cambium or phellogen ; *r*, inner green cells, the phelloderma. (After Prantl.)

The dicotyledonous stem now consists of the following parts :—

1. *A ring of epidermis* and cells with it becoming dried and dead.
2. *A ring of cork tissue* (outer bark) with the cork cambium within.
3. *A ring of phelloderma* (middle bark).
4. *A ring of phloëm*, interrupted by the passage of the medullary rays, and forming the bast (liber, or inner bark).
5. *A ring of cambium*, also interrupted by the passage of the medullary rays.

6. *An interrupted ring of xylem or wood.*
7. *A central pith or medulla.*
8. *The medullary rays*, uniting the pith with the middle bark (see fig. 65).

In the monocotyledonous stem (fig. 67) there is quite a different arrangement. On the exterior there is no differentiated

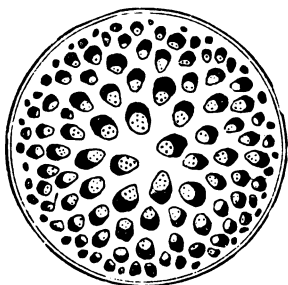


FIG. 67.—Diagrammatic representation of the distribution of the fibro-vascular bundles in the transverse section of a Palm stem.

bark ; within, no separation into pith and medullary rays ; but a number of bundles of procambium scattered amongst the general ground or fundamental tissue. These bundles differ in their development as well as in their arrangement from those of the dicotyledonous stem. Instead of leaving a layer of vitally active cambium, they are entirely converted into xylem and phloëm.

Dicotyledonous bundles which contain cambium are spoken of

as **open**, whilst those bundles which are destitute of this formative tissue, as those of **monocotyledons**, are known as **closed**.

We must now note a little more fully the structure and functions of the various parts of the dicotyledonous stem.

1. The **medulla** or **pith** consists entirely of parenchymatous cells, generally dodecahedral in shape, and it forms a cylindrical axis at or towards the centre of the stem. In the earlier stages the cells usually contain a little chlorophyll, and are filled with nutrient substances ; later on they become dry and colourless, and filled with air, and no longer serve any purpose in the life of the plant, so that the stem may be hollowed, all the pith having disappeared, and yet the plant may be living vigorously.

The amount of pith varies much in different plants. In hard-wooded plants, as the Ebony, it is very small ; whilst in soft-wooded plants, as the Elder, it is much larger.

2. Surrounding the pith there is a layer of spiral vessels (the **medullary sheath**), which is in reality the commencement

of the wood or xylem. The function of these vessels, as indeed of all true vessels, is to serve as air-carriers. Like the wood, cambium, and liber, the medullary sheath is pierced by the medullary rays.

3. Outside the medullary sheath comes the **xylem**, or wood, arranged in the form of concentric rings. These rings are formed as follows. During the first year the cambium cells by their division have caused the wood and liber to increase in thickness. During the winter the cambium remains dormant,

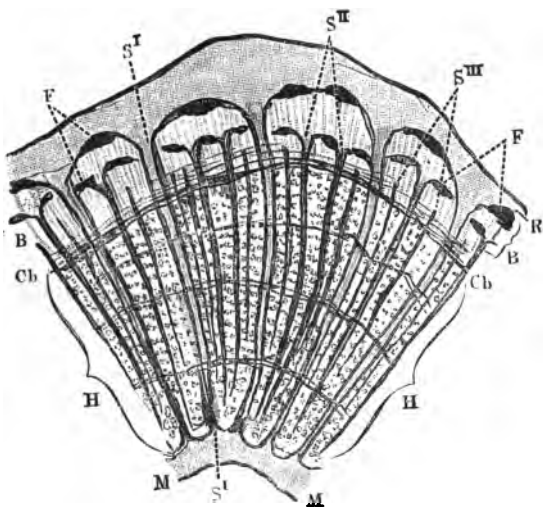


FIG. 68.—Portion of the transverse section through a shoot of Ivy four years old: R, cortex; B, bast bundles; H, wood, in which the four annual rings are distinctly visible: M, pith; S', medullary rays; F, bast fibres; Cb, cambium; S'', primary, S''', secondary bundles.

but as soon as spring returns the cells once more become vitally active, and form a fresh ring of wood on its interior *outside* the old xylem, and a fresh ring of liber on its exterior *inside* the old phloëm. Thus year by year fresh rings of wood and liber are formed (fig. 68), the oldest wood being towards the centre of the tree, whilst the oldest bark is towards the exterior. Growth such as this is sometimes spoken of as **exogenous**, and dicotyledonous plants are sometimes termed *exogens*. It is,

however, only the wood which is exogenous in growth ; the liber is endogenous.

As fresh rings of wood are as a rule formed every year, the age of a tree can generally be approximately ascertained by counting the number of the rings. The annual rings of various trees differ very much in the extent of their thickness, much depending not only on the nature of the plant itself, but also on its age and the atmospheric conditions of the climate. Also in the same plant the rings are not of equal thickness all round, so that the pith, instead of being geometrically in the centre of the tree is generally more or less excentric.

When these wood rings are fully developed they consist of three elements, viz.—

- (a) Wood fibres or wood prosenchyma.
- (b) Vessels, either spiral, annular, pitted, or otherwise.
- (c) A variable quantity of wood parenchyma.

These three elements are variously arranged, and any one of them may be absent. Generally there is plenty of secondary deposit, so that the cells have become hard. The inner wood is, as we have seen, the oldest, and hence the hardest, and is often coloured by the secondary deposit having colouring matter. This is especially well seen in such wood as Ebony, Camelthorn, Stinkwood, etc. In other cases, as in the Poplar and Willow, the old wood is nearly as colourless as that of the exterior. This inner wood is known as the heart-wood.

The xylem on the exterior, which is younger, is permeated with sap, and is known as the sap-wood.

The heart-wood is principally useful in supporting the plant, so that it may be absent as well as the pith without interfering with the vital activities of the tree.

In the sap-wood the vessels are mostly air-carriers, whilst the fibres are sap-distributors carrying a current of sap from the root up towards the leaves (see Chapter XII.).

4. Outside the xylem there is the interrupted ring of **cambium**, consisting of prosenchymatous cells dormant during the winter, and in full activity on the return of spring. After the first year cambium is formed between the fibro-vascular bundles (*interfascicular cambium*), thus making the cambium ring

complete (see figs. 65 and 69, B). By means of this interfascicular cambium, not only are the medullary rays lengthened as the stem increases in thickness, but also fresh phloëm and xylem are produced between the original bundles.

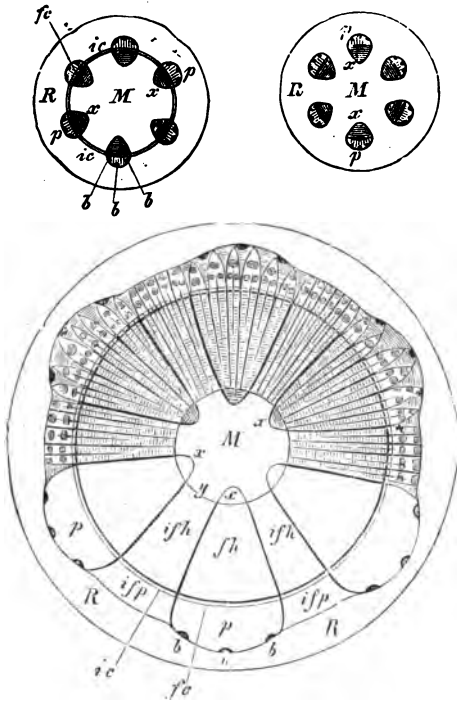


FIG. 69.—Diagrammatic view of the structure of a dicotyledonous stem with circumferential growth as seen in transverse section. *A*—*M*, *R*, Ground tissue forming pith (*M*) and cortex (*R*), the external ring representing the epidermis. Six fibro-vascular bundles separate—*x* the xylem, and *p* the phloëm of each bundle. *B*—Older stem: the bundles now united by cambium ring of fascicular (*fc*) and interfascicular (*ic*) cambium; *b*, *b*, the primary bast fibres of the phloëm. *C*—Still older stem. By the activity of the cambium new wood and bast have been formed. *fh*, wood formed by fascicular cambium; *ifh*, wood formed by interfascicular cambium; *ifp*, interfascicular phloëm; *x*, *y*, medullary sheath. The shaded upper part shows medullary rays. (After Sachs.)

5. Outside the cambium there is the interrupted ring of phloëm, liber, or inner bark. Like the wood, this consists of three elements, viz.—

- (a) The bast vessels or sieve tubes (fig. 36).
- (b) Bast fibres.
- (c) Bast parenchyma or soft bast.

The separate annual layers of the liber cannot, as a rule, be so readily distinguished as those of the wood, they being much thinner and compressed together by the growth in thickness of the tree. In some cases, however, the liber can be separated into thin plate-like layers.

A good example of this is to be seen in the Lace-bark tree (*Lagetta linearia*) of Jamaica, where the inner bark separates into thin sheets having the appearance of lace, the holes in it being the perforations for the passage of the medullary rays.

The fibres of the bast act as sap-circulators, bringing down the elaborated sap from the leaves.

6. The *green layer*, or *phelloderm*, consists of chlorophyll-containing cells, often intermixed with laticiferous vessels.

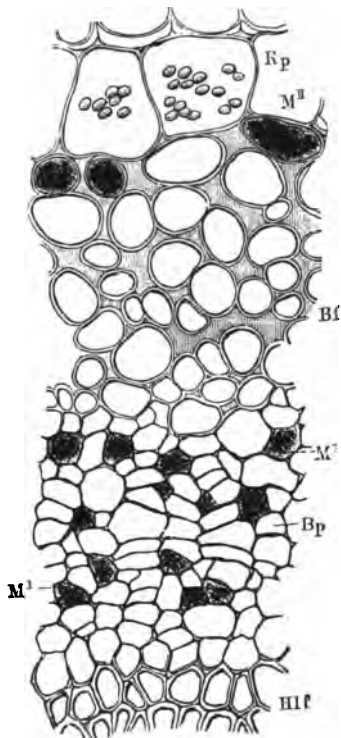


FIG. 70.—Part of a transverse section through the bast of the Wild Lettuce (*Lactuca scariola*): Bf, bast fibres; Bp, bast parenchyma; M, outer, M' inner laticiferous vessels; R, cortical parenchyma; Hf, wood-fibres.

7. The *outer* or *cork layer*

with its formative phellogen immediately beneath it. These two last layers form a protective coat to the exterior of the stem. After a short time the cells generally become dead, and very often peel off under the expanding influence of the growth of the stem.

This, as is seen in old Blue-gums or the Cork Oak, gives a rugged appearance to the bark. In other cases, owing to

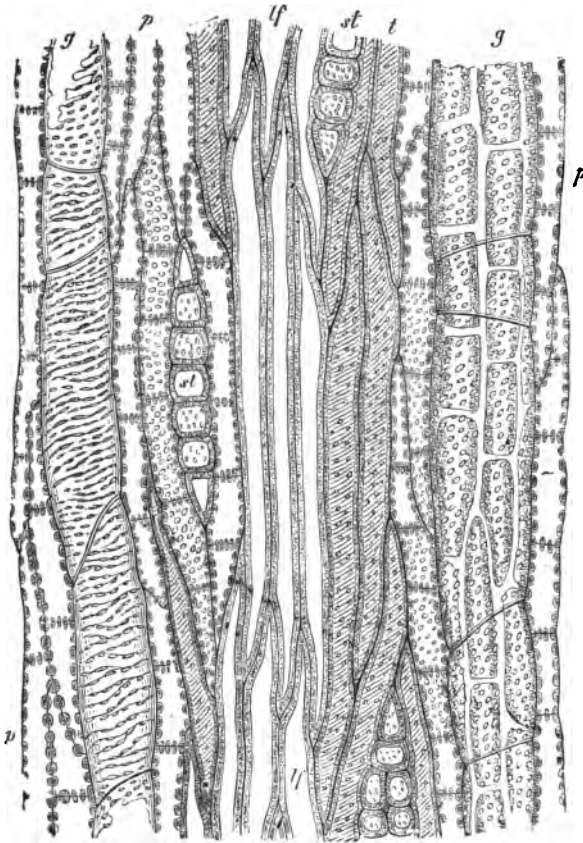


FIG. 71.—Longitudinal tangential section of stem of *Ailanthus*, showing secondary xylem of fibro-vascular bundles: *g, g*, wood vessels; *p*, wood parenchyma; *t, lf*, wood prosenchyma, of two varieties; *t*, tracheides, with pitted and spiral markings, and *lf*, libriform or bast-like wood fibres; *st*, medullary rays cut across. (After Sachs.)

its capability of distension, the bark presents a smooth appearance.

8. The **medullary rays** uniting the pith with the middle

bark, and separating the fibro-vascular bundles. They are generally made up of flattened, six-sided cells, arranged like bricks in a wall (*muriform parenchyma*).

The rays are rarely continuous from the top to the bottom of the stem, being separated by the fibro-vascular bundles (*st*, fig. 71).

The medullary rays form what is known as the "silver grain" of the cabinet makers. The use of the rays is to distribute the elaborated sap from the liber through the other parts of the stem.

In most cases the fibro-vascular bundles are continuous with those which form the veins of the leaves, and are known as "common bundles," *i.e.* common to leaf and stem. At the nodes (the point of attachment of the leaf to the stem) these bundles enter the stem and run down parallel to one another, usually through two or three internodes. At the nodes the bundles branch and interlace in various ways, whilst they thin out the further they descend.

The direction of the fibro-vascular bundles can be readily traced by making a longitudinal section of a young stem, taking care to cut through at least two nodes, and then soaking it for five or ten minutes in a solution of aniline sulphate acidulated with a few drops of sulphuric acid; the lignin of the bundles will be stained yellow, and hence their position can be noted.

STRUCTURE AND FUNCTIONS OF THE PARTS OF A MONOCOTYLEDONOUS STEM.

Even in their external form monocotyledonous stems present a different appearance from the dicotyledonous stems described. The Palms (fig. 72) and arborescent Liliaceæ, *e.g.* Aloe, instead of having tapering stems like our forest trees, possess them of much the same diameter from top to bottom.

Within there is no separation into pith or bark. On the exterior there is an epidermis and a cortex, or false rind made up of the ends of the fibro-vascular bundles. These bundles enter the stem from the bases of the leaves, being continuous

with the bundles present in them. At first they are narrow. They grow inwards, and then pass down the interior of the stem, gradually increasing in diameter. At length, having



FIG. 72.—*Livistonia australis*, a Fan Palm.

attained their largest size, they begin to curve outward again, thinning as they do till they end at the exterior (fig. 73).

The bundles are closed, containing no cambium, hence

after their formation they cannot increase in size. A section across the stem will show the younger bundles within and the older ones without. Such a mode of growth is often termed **endogenous**, but it must be borne in mind that it is only at a part of their passage that this is true, as at the commencement and end they grow outwards.



FIG. 73.—Course of the vascular bundles of *Iris* in longitudinal section (diagrammatic).

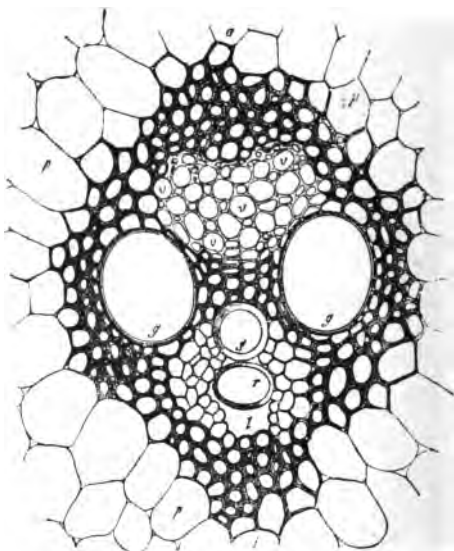


FIG. 74.—Transverse section of fibro-vascular bundle of *Zea Mays*: *p*, thin-walled parenchyma of ground tissue of, *a*, outer and, *i*, inner part of stem, with thick-walled prosenchymatous ground tissue internal to it; *g*, *g*, large pitted vessels; *s*, spiral vessel; *r*, isolated ring of annular vessel; *l*, air-cavity; *v*, *v*, cambiform tissue or soft bast. (After Sachs.)

In annual and herbaceous monocotyledons the ground tissue is soft and delicate; but in trees, as Palms, it is much hardened by secondary deposit, forming *woody parenchyma*.

It follows from this structure that it is impossible for such a stem to increase in thickness after the outer rind has become thoroughly hardened.

In some Monocotyledons of the Lily tribe, as the Aloe and *Dracæna* (fig. 75), there is a provision for the exogenous

formation of new bundles, but in a different manner from that which takes place in Dicotyledons.

A layer of meristem is formed in the outer part of the ground tissue, by means of which the stem is increased in thickness, and in which new fibro-vascular bundles are formed.

In Monocotyledons the sap rises to the leaves through the xylem of the bundles, and descends through the phloëm, and apparently partly by the parenchymatous tissue.

EXTERNAL FORMS OF STEMS.

A section of the stem usually shows it to be more or less cylindrical in shape; at other times it is angular, being either triangular, square, five-ribbed, etc. (fig. 76).

Generally stems are **erect**; if they trail on the ground they are **prostrate**; if, whilst thus reclining, they rise towards their extremities, they are **decumbent**; or if they gradually rise from near the base, **ascending**.

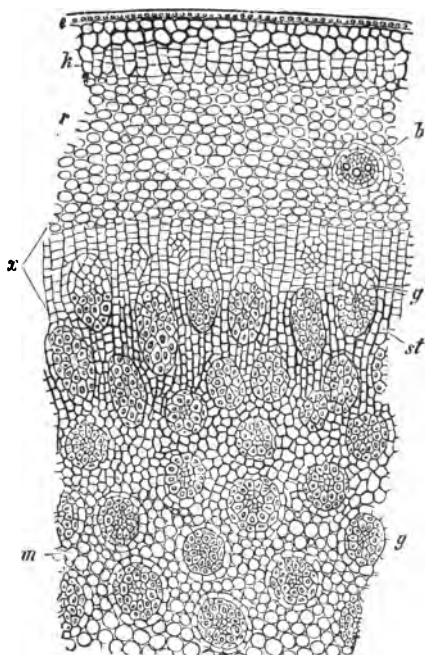


FIG. 75.—Transverse section of stem of *Dracena*, near apex: *e*, epidermis; *k*, cork; *r*, cortical portion of ground tissue; *b*, fibro-vascular bundle to leaf; *m*, ground tissue of centre of stem; *g*, fibro-vascular bundles; *x*, meristem zone, developing new fibro-vascular bundles (*g'*) and new ground tissue (*st*). (After Sachs.)

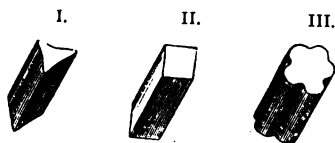


FIG. 76.—I. Section of triangular stem. II. Section of square stem. III. Section of five-ribbed stem.

Some stems are **climbing**, attaching themselves to some object of support either by *rootlets* (as in the Ivy), or by *tendrils* (as in the Passion Flower and Sweet Pea). Others are **twining** around the object of support, either to the left or to the right. The first case is more common than the second. Many *Convolvulaceæ* and *Asclepiadaceæ* twine to the left; the Hop, Honeysuckle, and *Testudinaria* to the right.

There are certain terms which are applied to various forms



FIG. 77.—I. Stem of *Convolvulus arvensis* twining to the left. II. Stem of Hop twining to the right.

of stems, some of which describe the *aërial* or above ground, and others the *subterranean* stems.

I. *Aërial* Stems.

(a) **The Runner**.—This is well seen in the Strawberry, where a branch springing from a plant creeps along the ground (often with a modified leaf or scale upon it), and ultimately strikes in the soil, producing leaves and roots, and forming a new plant (fig. 78).

(b) **The stolon**, as in the Honeysuckle, is really a branch

given off above the ground striking into the earth and giving off roots and leaves, forming a fresh plant. This is often imitated by gardeners in the process of layering, when they bend down a branch into the soil, thus causing it to take root and produce a fresh plant.

(c) **The Sucker.**—This differs from the last in being a branch

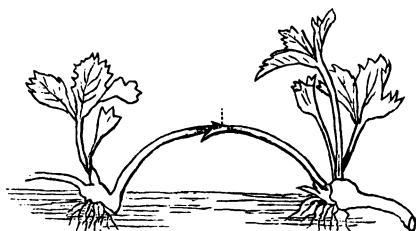


FIG. 78.—Runner of Strawberry (*Fragaria vesca*).

springing from beneath the soil, and after proceeding for a short time in a horizontal direction, giving off roots as it does so, turns up and grows out of the ground, forming a new plant. The Rose and Agave are examples.

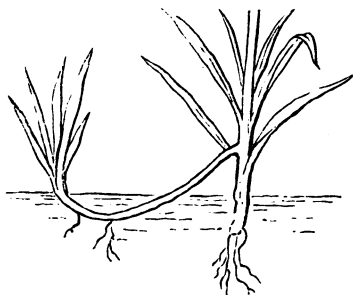


FIG. 79.—Stolon.

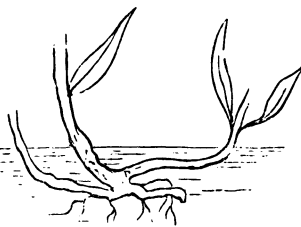


FIG. 80.—Sucker.

2. Subterranean Stems.

(d) The **rhizome** or **rootstock** is a thickened stem creeping either at the surface of the soil or just below it, giving off leaves from the upper surface, and roots from the lower. As the leaves fall off year by year, they leave scars marking where they had been. These, together with other subterranean stems,

are popularly termed roots, but are distinguished from true roots in the manner already indicated. Examples are to be found in the Arum, Sansevieria, Elephantorhiza, Ginger, etc. ;



FIG. 81.—Thickened rhizome of *Aponogeton distachyon*.

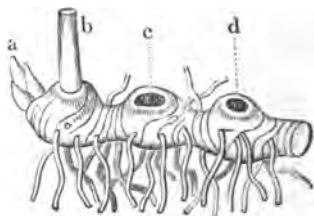


FIG. 82.—Rhizome of *Convallaria Polygonatum* : *a*, terminal bud from which is developed the next year's stem ; *b*, this year's stem ; *c*, *d*, scars of the stems of previous years.

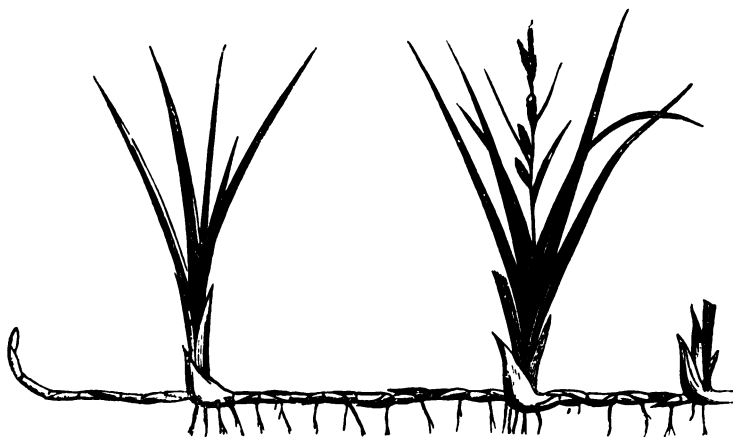


FIG. 83.—Creeping rhizome of *Carex*.

also in the Sand Sedge (fig. 83) and Couch Grass. In the former plant it is often of great use in binding together the loose sands of the sea-shore, whilst in the latter it is a pest to the farmer.



FIG. 83A.—Creeping rhizome of *Commelina Africana*, with buds.

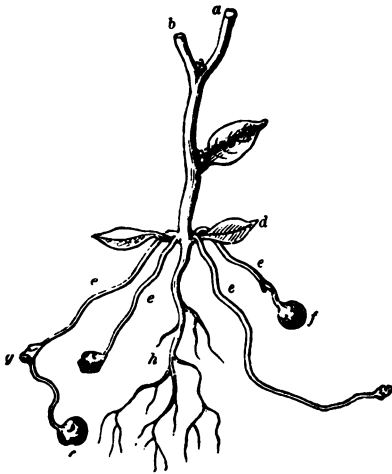


FIG. 84.—A six-weeks-old Potato plant, developed from the seed, the upper branches, *a*, *b*, being cut off: *d*, cotyledons; in the axils of the cotyledons are developed the underground branches, *e*, *e*, which penetrate into the ground and form tubers, *f*, *g*, at their apex or in the axils of small leaves. The tubers are formed only on the branches which are produced in the axils of the cotyledons, never on the true roots *h*.



FIG. 85.—*Eriospermum pubescens* (woody tuber).

(e) The **tuber** is a portion of an underground stem or branch, which is much swollen by the deposition of a large quantity of starch and other food materials. It possesses leaves which are more or less modified. In the Potato (which is a good example of the tuber) the eyes are the modified leaf buds. It is a well-known fact that if the aërial branches of a Potato plant are earthed, their growth will be arrested and tubers will be formed.

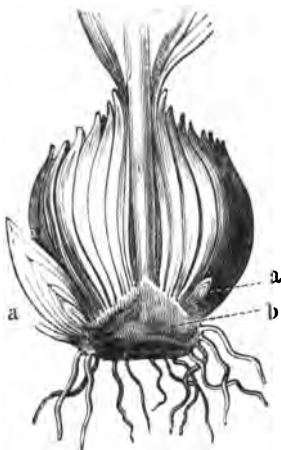


FIG. 86.—Tunicated bulb of the Onion: *b*, plate or disc; *a*, bulbils.

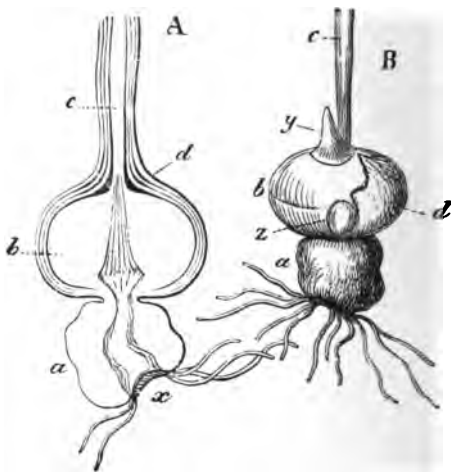


FIG. 87.—Corm of *Gladiolus*. A, Longitudinal section: *a*, last year's, *b*, this year's corm; *c*, scape; *d*, scales; *x*, roots. B, After removal of the enveloping scales: *y*, bud, which will develop into next year's corm; *z*, bulbil.

Other examples of tubers are to be seen in the Jerusalem Artichoke and Cyphia.

The large tessellated tuber (over-ground) of *Testudinaria* is the thickened hypocotyledonary part of the stem.

(f) The **bulb** consists of a more or less flattened, disc-like stem, giving off roots below, and scale-like leaves, together with stem and flowers, above.

The scale-like leaves have the power of developing in their

(g) The **corm** differs from the bulb in being much more solid, consisting of a larger disc and fewer scale-leaves. Examples are to be met with in the *Gladiolus*, *Moræa*, *Watsonia*, *Antholyza*, etc. Some of these are edible (*Uintjes*).

Duration of Plants.—Some plants complete their cycle of life (from the germination of the seed to the production of seeds) within one year, and then die; *e.g.* Sunflower and Maize. These are called *Annuals*. Others, *e.g.* Carrot, Beet, Cabbage, Turnip (see p. 37), require two years or seasons for the same development. These are called *Biennials*. *Perennials* are all those which last more than two years, producing fresh flowers and fruits annually after they have once reached their state of maturity; *e.g.* all trees and shrubs, and all herbaceous plants with underground stems.

axils smaller bulbs or buds known as *bulbils* (a, fig. 86). There are two forms of bulb. When the inner scales are fleshy, and are covered by thin membranous ones, the bulb is said to be *tunicated*, as in the Onion. If there be no outer tunic, as in the Lily, the bulb is said to be *scaly* or *naked*.

CHAPTER VII.

BUDS AND RAMIFICATION.

BRANCHES of the stem first make their appearance as buds. These as a rule do not appear indiscriminately, but at certain definite parts of the plant, viz. at the extremities of the stem



FIG. 88.—*a*, Terminal bud; *b*, axillary bud, the leaf in the axil of which it was produced having been removed.

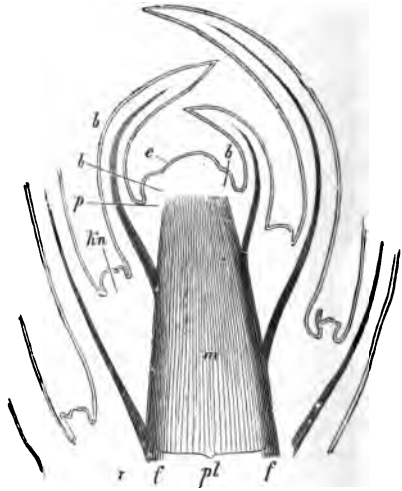


FIG. 89.—Diagram of a longitudinal section of the apex of the stem of a dicotyledonous plant: *m*, pith; *f*, fibro-vascular bundles, both developed from the pleurome (*pl*), the bundles sending branches to the leaves; *r*, cortical tissue; *e*, epidermis; *b, b*, young leaves, two showing their origin from protomeristem (*p*); *kn*, axillary bud. (After Prantl.)

and branches, when they are called **terminal buds**; and in the axils of the leaves, that is to say, the angle formed between the leaf and the stem, when they are termed **axillary buds**.

If they grow from any other part of the plant they are said to be **adventitious**.

At first the bud consists entirely of parenchymatous tissue connected with the parenchyma of the stem. There is a central conical mass around which, after a while, vessels and wood cells are developed; outside these, parenchymatous tissue which forms bark, and which is covered with little scales of parenchyma variously overlapping one another, forming the rudimentary leaves.

The portions of the young stem to which these leaves are attached are known as **nodes**, whilst the stem between the nodes forms the **internodes**.



FIG. 90.—Spines of *Celastrus cuxifolius*, L.



FIG. 91.—Prickles of the Rose.

In cold and temperate climates, where the buds remain dormant during the winter, unfolding during the following spring, the outer surface is protected by modified scales, which sometimes, as in the Horse-chestnut and Poplar, possess resinous secretions, and at other times, as in Willows, are covered with hairs. These scales protect the young bud from the cold and frosts of the winter, and fall off when it begins to develop in the following spring.

The commencement of the development of the bud is by the growth of the internodes, by which the young leaves become gradually separated from one another and the branch is formed.

If all the normal buds of the plant were developed, the branching would follow regularly the arrangement of the leaves.

This uniformity is often interfered with: 1st, by the non-development of buds; 2nd, by the formation of adventitious buds.

Sometimes many of the buds remain entirely undeveloped. At other times, instead of being developed into leaf-bearing branches, they form subsidiary organs.

1. **Spines** are often modified branches. They are met with in *Celastrus* (fig. 90), Kei Apple, Orange, etc. At times they are small and destitute of leaves; often they bear leaves.



FIG. 92.—Stem tendrils of the Grape-vine: *v*, in the normal state; *v'*, bearing a bunch of grapes.

There is a great difference between spines (as in the Orange) and prickles (as in the Rose and Bramble). In the former case the spines are modified branches, and as such are connected with the internal parts of the stem; in the latter case the prickles are simply hairs of the epidermis which have become hardened by the deposition of secondary deposit.

2. **Tendrils**.—Sometimes the buds become developed as tendrils, as in the Grape Vine, enabling the plant to hold on

to the object of support.

Both spines and tendrils *may* be modifications of parts of leaves. The spines of some species of *Acacia* and *Robinia* (fig. 113), and the tendrils of the Sweet Pea (fig. 93), *Bignonia* (Orange creeper), and wild *Clematis*, are examples.

We can tell, however, which they are by their position. If they are in the axils of leaves, they are modified branches; if

upon the stem or forming part of the leaf, they are modified leaves.

In some cases adventitious buds are formed beneath the bark, and are not developed externally. In such cases they produce considerable variations in the figure and grain of the wood. Bird's-eye Maple is a very good example of this.



FIG. 93.—Sweet Pea (*Lathyrus odoratus*).

Buds are often capable of being removed from one plant and made to grow upon another of the same family. Upon this fact depend the important operations of **grafting** and **budding**.

In grafting, a branch of a superior variety, possessing buds, is taken and implanted on a wild stock (fig. 94). The

formative cambium round the wound grows, forming a protective succulent cushion of tissue known as a *callus* (fig. 95). The



FIG. 94.—Grafting: *d*, the stock to which the graft is attached.

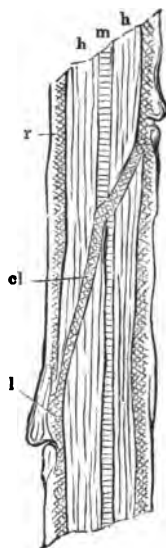


FIG. 95.—Diagrammatic representation of a longitudinal section through a graft: *cl*, the callus; *r*, bark; *m*, pith.

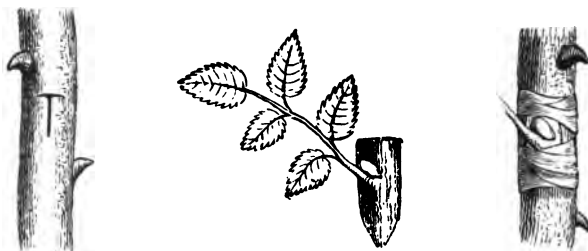


FIG. 96.—The various elements in the process of budding.

graft grows independently of the stock, receiving, however, its nourishment through it.

In budding, a bud, together with the surrounding bark, is

removed from a superior variety, and a T-shaped incision is made in the stock, beneath which the bark of the bud is inserted, the whole being bound round to protect it from the action of the atmosphere (fig. 96).

The bud grows in the same way as the graft.

The terms **vernation** and **præfoliation** are employed to express the way in which the young leaves are arranged in the bud.

CHAPTER VIII.

STRUCTURE AND FUNCTIONS OF LEAVES.

WHEN a leaf is complete, it consists of three parts: 1. The flat expanded portion which is popularly called the leaf. This is the **lamina**, or **blade**. 2. The stalk, which attaches this

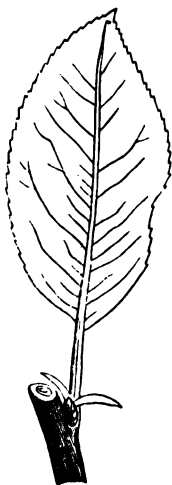


FIG. 97.—Oval leaf of the Apple, with two free stipules.



FIG. 98.—Branch of a young plant of *Acacia melanoxylon*, showing phyllodes, *a*, *b*.

to the stem, the **petiole** or **leaf-stalk**. 3. The little leaf-like projections at the point of union between the petiole and the stem, the **stipules** (fig. 97).

In very many cases, however, there are only one or two of these parts present. If the petiole be absent, the leaf is said to be *sessile*; if the stipules, *exstipulate*.

The Wallflower and Shepherd's-purse are examples of plants with leaves which consist of lamina only. In some of the leaves of the Australian *Acacias* (fig. 98), we have only the petiole developed. It grows in a flattened leaf-like expansion known as a *phyllode* (fig. 98, *a*, *b*).

In structure the leaf consists of parenchyma, which is intimately connected with the outer parenchyma of the stem and prosenchyma forming the veins, and which is in like manner connected with the xylem and phloem.

In a vertical section through the leaf we find the following parts (fig. 99):—

1. A flattened epidermis coating the upper (*b*) and under (*e*) sides. As a rule, the under surface possesses a greater number of stomata than does the upper.

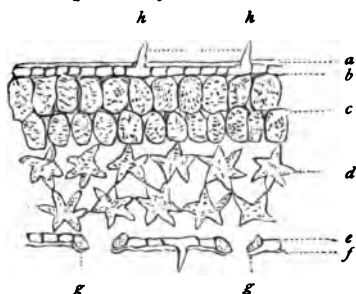


FIG. 99.—Diagrammatic section of leaf: *a*, cuticle of upper, *f*, of lower side; *b*, epidermis of upper, *e*, of lower side; *c*, cells of upper side; *d*, stellate cells of lower side; *g*, *g*, stomata; *h*, *h*, hairs.

Professor Bentley gives the following table of the number of stomata found in a square inch of the two surfaces respectively of the various plants:—

	Upper surface.	Under surface.
Vine	None	13,600
Olive	..	57,600
Hydrangea	„	160,000
Mistletoe (<i>Viscum</i>)	200	200
Tradescantia	2,000	2,000
Aloe	25,000	20,000

To which may be added—

Silver-tree	100,000	100,000
Hæmanthus	10,000	2,000
Arctopus	15,000	1,600

Besides stomata, the epidermis is very frequently provided with hairs of various kinds.

These are simply prolongations of the epidermal cells, sometimes unicellular, sometimes multicellular (fig. 101).

They vary much in their shape, sometimes being simple and at other times branched.

An interesting modification is seen in glandular hairs which contain various secretions; of these stinging hairs, as are found in the Stinging-nettle, are good examples. In this case there is a little bag at the base of the hollow hair, containing an acrid fluid, and surrounded by a number of elastic cells. The point of the hair is sharp, and is protected by a little cap.

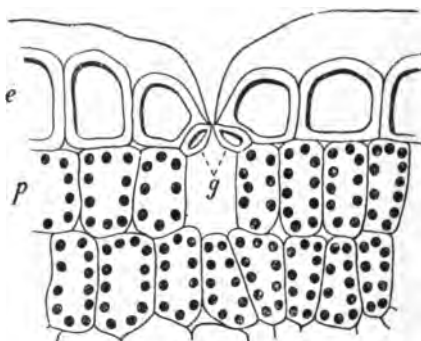


FIG. 100.—Stoma of *Welwitschia*: *e*, epidermis; *p*, green parenchyma; *g*, guard-cells.

When the nettle is touched lightly, the cap is broken off, the point of the hair pierces the skin, and a drop of the stinging juice is forced into the blood. If the nettle be grasped firmly the sting is broken lower down, and hence there is no sharp point to pierce the skin, and the juice is simply poured out upon the exterior.

2. The surface of the epidermis is generally covered with a thin structureless layer, the **cuticle** (figs. 99 and 100).

3. The parenchyma of the interior of the leaf consists of cells containing chlorophyll.

There is a difference, however, in their arrangement in the different parts of the leaf. Towards the upper surface the cells

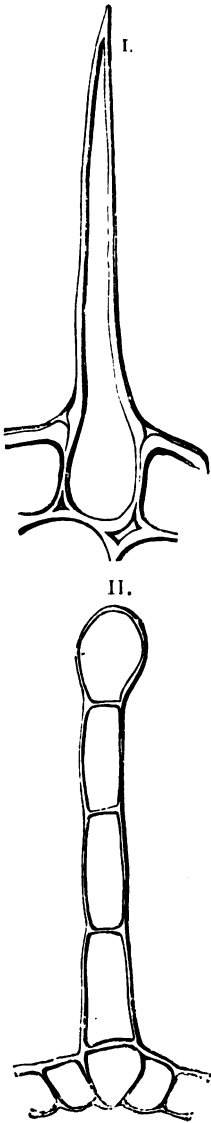


FIG. 101.—Simple hairs: I. Unicellular hair from the leaf of a *Pelargonium*. II. Multicellular hair from the stem of *Geranium pratense*.



FIG. 102.—Stinging hair of the nettle (*Urtica dioica*): the corroding fluid flows out of the hair when the vitreous knob-shaped apex is broken off.

are packed closely together (*c*, fig. 99), whilst towards the under surface we find examples of stellate parenchyma, leaving air-spaces between the cells (*d*, fig. 99). This is the cause of the fact that in most leaves the under surface is lighter in colour than the upper, as there is less chlorophyll packed there.

Such leaves are called "bifacial." There are, however, especially in dry regions, many plants with symmetrical leaves,

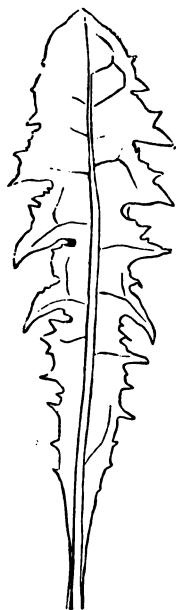


FIG. 103.—Runcinate leaf of the Dandelion, feather-veined.



FIG. 104.—Converging veined leaf of Cinnamon.

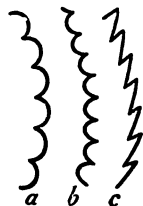


FIG. 105.—Margins of leaves: *a*, crenate; *b*, dentate; *c*, serrate.

both sides being similar in structure, *e.g.* Silver-tree, Blue-gum, several species of *Mesembryanthemum*, *Acacia*, *Aloe*, etc.

The upper parts of the veins are in direct communication with the wood of the stem, whilst the lower parts are connected with the liber. At the edges of the leaves there is a passage between the upper and lower sides, so that the sap which passes up the wood flows out through the upper part of the

veins, back through the under surface to the liber, and so down the stem.

There is a great difference in the **venation** or arrangement of the veins of the leaves in the two great groups of flowering plants.

In Dicotyledons the smaller veins run together, forming a complete network known as **reticulate venation** (fig. 106).

In Monocotyledons, as a rule, there is no network formed between the principal veins, and the venation is said to be **parallel**. (Some Monocotyledons, however, as the Aroids, have net-veined leaves.)

There are varieties of both net-veined and parallel-veined leaves.

In describing leaves, besides the venation, we have to take into account the following points: 1. Composition; 2. Margin; 3. Incision; 4. Apex; 5. General outline.

1. **Composition**.—Leaves are either **simple** or **compound**. In simple leaves, as in the Apple (fig. 97), there is only a single lamina; in compound leaves, as the Acacia (fig. 98), the lamina is divided into a number of leaflets articulated to the common petiole.

2. **Margin**.—The condition of this depends upon the extent to which the parenchyma is developed between the veins. The margin may be **entire**, as in Grasses. More often there are indentations.

If the teeth thus formed are rounded, the margin is **crenate**. If they are sharp, with round indentations between them, it is **dentate**. If sharp outwards and inwards, like the teeth of a saw, it is **serrate** (fig. 105).

If the margin of the leaf be covered with numerous hairs, it is **ciliate**. If there be alternate concavities and convexities



FIG. 106.—Lyrate leaf of the White Mustard (*Brassica alba*).

larger than crenated indentations, the margin is **sinuate** (fig. 107).

3. **Incision**.—We apply this term if the margin be more deeply indented than in the instances already described. If the indentations reach to midway between the margin and the midrib or petiole, we speak of them as **fissures**, and the portions of leaf between them as **lobes**, and the leaf is said to be *bi-, tri-, etc., -fid.* If the divisions go nearly to the base, or midrib, they are **partitions**, and the leaf is *bi-, tri-, etc., -partite.* If quite down to the midrib or base **segments**, the leaf is *bi-,*

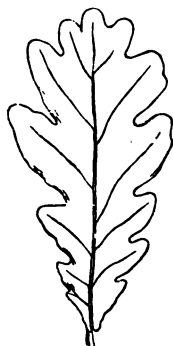


FIG. 107. — Sinuate leaf of the Oak.



FIG. 108. — Mucronate leaflet of the Lucerne.

tri-, etc., -sected. (For further remarks on this point see under the head of Outline.)

4. **Apex**.—If the apex of the leaf be rounded (fig. 107), it is **obtuse** or **blunt**. If it be sharp pointed (fig. 79), it is **acute**; and if it gradually tapers to a point, it is **acuminate**. When there is a rounded head, and a broad shallow notch in it, the apex is **retuse**, and when the notch is more triangular (fig. 204), it is **emarginate**. When the apex is very abrupt, as though cut off, it is said to be **truncate**.

When the apex is flattened and has a sharp point projecting (fig. 108), it is called **mucronate**.

5. **General Outline**.—Various terms are employed for the description of the general outline.

If, as in the Grasses and Rosemary, the two margins of the lamina are nearly parallel and the lamina itself is narrow, the leaf is **linear**.

If the leaf be sharp pointed and needle-like, as in many

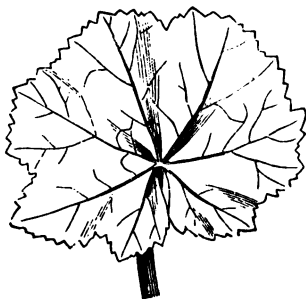


FIG. 102.—Orbicular leaf of *Malva rotundifolia*.



FIG. 110.—Cordate leaf of *Stachys athiopica*.

Conifers (fig. 265), it is **acero**se. When the leaf is somewhat broad in the centre, and tapers towards the two extremities, as in the Oleander, it is **lanceo**late (see fig. 267). If more rounded at the extremities and broader in the centre, it is **oval**, or **elliptical** (fig. 27). When the leaf is broad and rounded at the base, tapering to a point at the apex, it is **ovate**; and if the reverse, **obovate**.

When the leaf is nearly round (fig. 109), it is **orbicular**. When (fig. 110) the leaf is somewhat hollowed out at the base, and pointed at the apex,



FIG. 111.—Reniform leaf of *Hydrocotyle eriantha*.

so as to be roughly like a heart in a pack of playing-cards, it is **cordate**; and when the reverse, **obcordate**. If the apex is rounded, whilst the base is hollowed (fig. 111), it is **reniform**.

When the apex is rounded, and the leaf gradually tapers to

the base, e.g. young leaf of Lettuce, it is **spathulate**; or if it is more tapering, as in the leaflets of the Horse-chestnut, the outline is said to be **cuneate**.

When the leaf is somewhat of the form of an arrow-head, like that of our common Arum, it is called **sagittate**; or if the

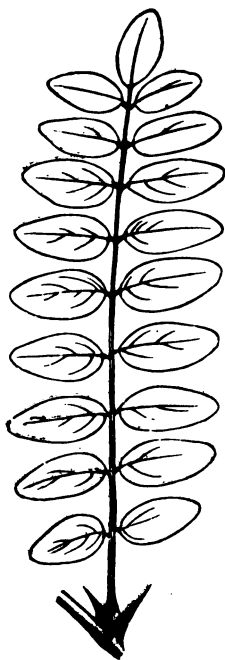


FIG. 113.—Imparipinnate leaf of the Locust-acacia (*Robinia Pseudacacia*) with opposite leaflets (and spinous stipules).



FIG. 112.—Hastate leaf of *Rumex acetosa*.

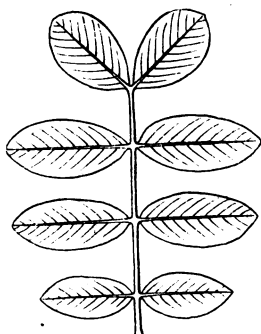


FIG. 114.—Paripinnate leaf of *Schotia latifolia*.

barbs of the arrow point out more at a right angle to the blade, the leaf is **hastate** (fig. 112).

There are also several terms which are applied to the outlines of compound and much divided leaves. Thus, if a compound has two leaflets, it is **binate**, e.g. *Bauhinia*; if three,

ternate (fig. 204). A **multifoliate** leaf has more than seven leaflets springing from a common point. When the leaflets are arranged on either side of the central stalk, like barbs on a feather, the leaf is said to be **pinnate**. Of these leaves there are two varieties, viz. **imparipinnate**, when there is an odd lobe at the extremity (fig. 113); and **paripinnate**, when the number of lobes present is even (fig. 114).

When a simple leaf is divided in a pinnate manner, it is **pinnatifid**, **pinnatipartite**, or **pinnatisected**, according to the depth of the incisions.

When each of the pinnæ of a pinnate leaf is itself pinnate,



FIG. 115.—Palminnerved leaf of *Geranium pratense* (nature-printed).

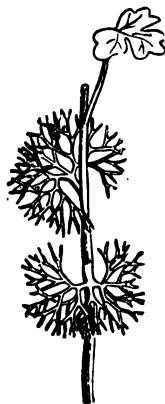


FIG. 116.—Heteromorphic leaves of the Water Crowfoot (*Ranunculus aquatilis*): the floating leaves trilobed, the submerged leaves laciniate.

the leaf is said to be **bipinnate**, *eg.* *Syringa* tree. If the division be carried a step further, it is **tripinnate** (fig. 236).

When the divisions of the leaf spread out like the fingers of a hand, the leaf is **palmate** (fig. 115), **palmatifid**, **palmatipartite**, and **palmatisected**.

When a palmatisected leaf is itself cut up into segments, it is **dissected** or **laciniate** (fig. 116).

There are certain terms which are applied to the attachment of the leaves to the stem. Thus when placed one above the other upon opposite sides of the stem, they are **alternate**. If

placed in pairs on opposite sides, they are **opposite**. If the alternate pairs of opposite leaves are placed at right angles to one another (fig. 117), they are **decussate**. When there are more than two leaves forming a whorl round the stem (figs. 118, 261), they are said to be **verticillate**. When two opposite



FIG. 117.—Decussate leaves of the Scarlet Pimpernel (*Anagallis arvensis*), with axillary flowers.

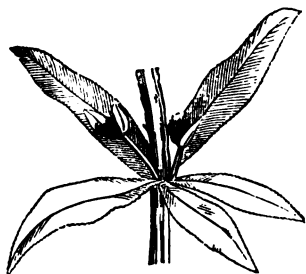


FIG. 118.—Verticillate leaves of the Madder (*Rubia tinctorum*).



FIG. 119.—Perfoliate leaf of *Bupleurum rotundifolium*.

leaves have their bases so united as to form apparently but one, often thus producing a cup, as in some species of *Crassula*, they are **connate**. If the base of the leaf, whether petiole, lamina, or stipules, embraces the stem (fig. 275), the leaf is **amplexicaul**, the part surrounding the stem being called the **sheath**.

If the stem apparently grows through the leaf, as in *Borbonia perforata*, the latter is said to be **perfoliate** (fig. 119), whilst, if any part of the leaf adheres to the stem, causing the latter to be winged, the leaf is said to be **decurrent**, e.g. *Printzia Bergii* and several species of *Stobæa*.

If the leaves grow from the point of junction of the root and stem, or if the stem be so reduced as to be almost obliterated, they are said to be **radical**. Leaves growing from the stem are called **cauline**.

FUNCTIONS OF THE LEAVES.

1. **To absorb food for the plant.**—We have already seen how the roots take up from the soil the various substances needed for the life of the plant. One very important substance, however, is not taken up by the roots of green plants, and this is carbon.

This element exists in the atmosphere in the form of carbon dioxide or carbonic acid gas, a compound of carbon and oxygen, CO_2 . It is produced wherever breathing, burning, and decay of organic bodies are taking place.

The composition of a thousand parts, by volume, of atmospheric air is as follows :—

Nitrogen	779·50
Oxygen	206·10
Water (variable), as vapour	14·00
Carbon dioxide	0·40
Various gases	traces
	1,000·00

That is to say that a thousand cubic feet of air contain not quite half a cubic foot of carbon dioxide. Small as this quantity may appear to be, it is the source of the carbon of the plant.

The carbon dioxide enters with the other constituents of the air by means of the stomata into the interior of the leaf, there to serve for the nourishment of the plant.

2. **To assimilate the food absorbed.**—The food materials which are taken up by the root are not changed as they are

carried up to the leaves. The sap becomes thicker by evaporation, but when it enters the leaves it still contains simply mineral substances. In the leaves, however, it is brought into contact with the carbon dioxide, and a marvellous change takes place. In the presence of the chlorophyll and under the action of light, the carbonic acid gas is decomposed: its oxygen is restored to the atmosphere, whilst the carbon is chemically united with the water and the mineral substances, to build up new and organic compounds. These changes will only take place in the light, and go on in all the green parts of the plants. It is owing to this that the amount of carbonic acid in the atmosphere is kept down, and the air purified and rendered fit for man to breathe; hence the importance of open spaces with trees in the midst of our cities.

A very important point to remember is, that plants as a rule do not absorb free nitrogen from the atmosphere, but take up all the nitrogen required in the form of compounds, principally as ammonia or nitrates.

To this general rule one natural order of plants forms a remarkable exception. Leguminous plants, namely, possess the power of utilizing the free nitrogen of the atmosphere under certain conditions.

On the roots of such plants, *e.g.* Bean, Pea, Lupine, Vetch, Indigo, etc., appear small tubercles, which are caused by some microbes, and it is under the influence and through the agency of these microbes that these plants are able to obtain all the nitrogen which they require from the air without being supplied with ammonia or nitrates. These plants are consequently called nitrogen-gatherers, and are largely cultivated without any nitrogenous manure. The system of "green manuring" is based upon their cultivation.

3. **As a breathing organ.**—Plants, like animals, carry on a process of respiration, *i.e.* they take in atmospheric oxygen, which combines with the carbon and hydrogen of the tissues, forming carbon dioxide and water, which are restored to the air. The respiration, however, of plants is much less than that of animals; it differs in its amount in various plants, and in the different parts of the same plant. The more energetic

the growth, the greater the amount of respiration : hence it is especially well seen in quickly germinating seeds, and unfolding leaf and flower-buds.

The oxygen passes into the interior of the plant by means of the stomata, and by the same openings the carbonic acid gas is passed out into the atmosphere. This change, which is a function of every living tissue, in the vegetable body as well as in the animal, goes on continually throughout the whole plant, irrespective of the presence or absence of light. During the daytime the feeding by the decomposition of carbon dioxide and assimilation of the carbon is so greatly in excess of the respiratory act, that it completely overshadows it, and apparently nothing is going on but the decomposition of the carbonic acid ; but in the night-time, when, owing to the absence of the light, no assimilation is taking place, the breathing can be perceived.

4. **As an organ of transpiration.**—A large portion of the water which is taken in by the roots of the plant escapes by the leaves. By means of this evaporation the sap becomes thickened as it ascends the stem. The transpiration takes place by means of the epidermis, and especially through the stomata. The amount which is evaporated depends upon certain conditions, viz.—

(a) The state of the atmosphere. All other things being equal, more moisture will be given off in dry than in moist atmosphere, and more in windy than in calm weather.

(b) The amount of light. The greater the light, the greater the transpiration.

(c) The structure of the epidermis. In many succulent plants the epidermis is very thick, thus preventing an excess of evaporation.

(d) There is a greater evaporation from the lower than the upper sides of the leaves.

The amount of water transpired is often very great, as is shown by experiments which were first performed by Hales in 1724. A Sunflower plant, $3\frac{1}{2}$ feet high, weighing 3 lbs., and with a surface of 5616 square inches, exhaled a pint of water a day ; a Cabbage plant with 2736 square inches, 19 fluid

ounces ; a Lemon tree with 2557 square inches, 6 fluid ounces.

The action of Wardian cases depends upon this continual evaporation. By this means the water which evaporates collects on the glass, and, running down once more, waters the plants.

The transpiration of plants also plays an important part in determining the humidity of the atmosphere where they grow. We always find that if there are forests of trees the atmosphere in the neighbourhood is moist ; whilst, on the other hand, there have been numerous cases where the clearing of a large tract of country has materially interfered with the rainfall.

5. **As organs of circulation.**—From the fact of transpiration follows the next, that the leaves tend to produce a flow of sap upwards. As evaporation takes place there is a continual flow of water up the wood to take its place ; the greater the evaporation the more rapid the sap circulation (see Chapter XIII.).

The foregoing functions are performed by all leaves ; the following, however, are exceptional :—

6. **In some cases the leaves act as insectivorous organs.**—Some plants seem to possess the power of absorbing their nitrogen by means of organic compounds containing it. Good examples are to be seen in Venus's Fly-trap (fig. 120), and the Sundews of our own country. If we examine the leaves of a Sundew (*Drosera*), or of the curious shrub *Roridula*, we find that their upper surfaces are covered with glandular hairs, each of which is crowned with a small drop of a sticky fluid. If an insect settles upon the leaf, it becomes arrested, the neighbouring hairs bend towards the victim, and the leaf gradually folds over, enclosing it. It thus remains closed for some time, hours or days as it may be, and on opening again there is found merely the outer shell of the insect, all the nutritive matter having been absorbed by the plant. The leaf seems to contain a substance analogous to, if not identical with, the pepsine of the animal stomach, which possesses the power of rendering nitrogenous substances soluble.

Other insectivorous plants, e.g. *Nepenthes*, a so-called

pitcher plant, have the same power of absorbing organic food-materials by their leaves in various ways.



FIG. 120.—Venus's Fly-trap (*Dionaea muscipula*).

7. In some cases the leaves act as organs of support.—We have already seen that parts of the leaf may be converted into tendrils (fig. 93), thus twining round the organ of support

and sustaining the stem. In the *Tropæolum*, *Clematis*, and *Bignonia* the leaf-stalk itself twines and supports the plant.

Parasites.—It has been noted (p. 34), that some plants obtain their food through the medium of others. Such plants are known as parasites. We may divide them under three heads.

(a) **Semi-parasites.**—These can obtain some food from the soil, but not sufficient to enable them to grow in a luxuriant manner.

If some seeds of *Melampyrum* be allowed to germinate in earth they will grow, but the plants will not be fully developed. If, however, the seeds be sown amongst some grass, strong, well-developed plants will be obtained.

In the latter case the plants send their roots into the roots of the grass and draw sap out of them, which is afterwards elaborated in the leaves of the parasite.

(b) **Green parasites.**—Mistletoe (fig. 61) is a type of this class. It cannot obtain any nourishment for itself out of the soil, and has to depend entirely upon the tree into whose stem it sends its roots. At the same time its leaves contain chlorophyll, and hence it can decompose the carbon dioxide of the atmosphere, and assimilate food for itself.

The English mistletoe (*Viscum album*) has numerous relatives in South Africa belonging to the genera *Viscum* and *Loranthus*. They are common on many trees, e.g. Apple and Fig trees, Acacias, Tamarisk, etc.

(c) **Perfect parasites.**—Of this group *Harveya*, *Hyobanche*, *Hydnora*, etc., which grow on the roots of other plants, and *Cassytha*, which, like the dodder, grows on the stems, are types. These plants possess no chlorophyll, hence they cannot decompose the atmospheric carbon dioxide, so they obtain from the plants on which they live sap which is already elaborated.

On the root-parasites mentioned, the leaves are modified into scales destitute of chlorophyll, whilst in the dodder they are entirely absent.

The dodder (*Cuscuta racemosa*) is sometimes detrimental to lucerne fields, whilst the *Cassytha* is often invading shrubs

of *Rhus*, *Stæbe*, etc., or even Oaks and Silver trees, destroying them gradually.

In the forests of Java occur some root-parasites with flowers more than three feet in diameter (*Rafflesia*).

8. **Leaves are sometimes storehouses of reserve material**, e.g. Cabbage and Agave (*A. Americana*). In the latter case the



FIG. 121.—*Mystacidium gracile*, Hard. Epiphyte in the Eastern forests.

assimilated material is stored up in the leaves year after year until the quantity is large enough (in seven to ten years) to produce the flowering shaft. This done and the seeds ripened the plant dies, having exhausted its energy.

Epiphytes do not draw any sap or food from the trees on which they grow. The tree is merely the support, but not the feeder of its "tenant." The latter obtains its supply of food and water from the atmosphere and the decaying vegetable matter which accumulates between its roots or branches (fig. 121).

CHAPTER IX.

BRACTS AND INFLORESCENCE.

THE term **bract** is employed for those leaves in whose axils flower-buds instead of leaf-buds arise, or for any appendage growing upon the flower-stalk below the flower.

These appendages are generally smaller than ordinary leaves, and of simpler shape.



FIG. 122.—Capitulum of Marigold, with imbricate involucre.

Sometimes the bracts are coloured, being then often mistaken for the true flowers, as in the Hydrangea, Poinsettia, Bougainvillea, and several species of Proteaceæ, e.g. Sugar-bush. In other cases the bracts are small and scale-like.

When several bracts surround a single flower, as in the Pink, or a head of flowers, as in the Marigold (fig. 122), they form an **involucre**.

When a single bract is enlarged and ensheaths a single flower whilst in the young state, as in the Narcissus, or an inflorescence, as in the Arum and Palm, it is called a **spathe** (fig. 126).

The scaly bracts which enclose the flowers of the Grass and Sedge tribes are *pales* and *glumes*.

If the bracts fall before, or soon after, the flower opens, they are *deciduous*; whilst if they remain (sometimes even to the ripening of the fruit), *persistent*.

If bracts be present, the plant is said to be *bracteate*; if absent, *ebracteate*.

The term **inflorescence** is employed to describe the arrangement of the flowers upon the stem. In some cases, as in several orchids, there is a single flower at the top of the stalk, no others being formed below. More often there are several flowers variously arranged. Inflorescences are divided under two heads.

If we examine such a bunch of flowers as the Snapdragon



FIG. 123.—Simple raceme of *Antirrhinum majus*.



FIG. 124.—*Dianthus Caryophyllus*: portion of plant with definite inflorescence.

(fig. 123), or Wallflower, or Stock, we find that the oldest flowers are towards the base, the younger ones being towards the apex. Such an inflorescence is said to be **indefinite**. Sometimes in the indefinite inflorescences, as in the Sunflower or Everlasting, the flowers, instead of being arranged one above another, are side by side. In this case the younger

flowers are towards the centre, and the older ones around them. In the Pink, on the other hand (fig. 124), the stalk is capped by a flower which is the first to open, the younger ones budding below it. This is termed **definite inflorescence**.

Of each of these forms there are several varieties.

Indefinite Inflorescence.—In the case of the indefinite inflorescence the axis may either be lengthened, as in the Snapdragon, or arrested, as in the Marigold and Dandelion ; and in either case the flowers may be sessile or stalked.



FIG. 125.—Simple umbel of the Cherry.

A **spike** is an indefinite inflorescence with a lengthened axis and sessile flowers, as in the Gladiolus, Watsonia, Wheat, or Brabejum (fig. 261).

A **raceme** is an indefinite inflorescence with a lengthened axis and stalked flowers, as in the Snapdragon (fig. 123), many Cruciferae, and orchids.

A **capitulum**, or flowerhead, is an indefinite inflorescence with shortened axis and sessile flowers, as in the Marigold, Everlasting, Protea, etc. (figs. 242, 263).

An **umbel** is an indefinite inflorescence with shortened axis and stalked flowers, as in the Cherry (fig. 125), Nerina, Amaryllis, and many heaths (fig. 253).

If each branch of the umbel be itself branched, the *compound umbel* is produced, as in the Caraway, Bubon (fig. 236), etc. Special names are given to varieties of some of these forms.

VARIETIES OF SPIKE.

A **catkin** or **amentum** is a deciduous spike of unisexual flowers, as in the Oak (fig. 264) or Willow.

A **spadix** is a fleshy spike bearing several unisexual flowers, the whole enveloped in a spathe, as in *Richardia*, the so-called Arum (fig. 126).

A **cone** is a spike of unisexual flowers with lignified bracts, as in the Fir (fig. 266) and Silver Tree.

VARIETIES OF RACEME.

A **corymb** is a raceme where the stalks or pedicels are of different lengths, the lower ones being the longest, so that the



FIG. 126.—Spadix of *Richardia africana* with one half of spathe. The pistillate flowers are below, the staminate flowers above.

flowers form a flat-topped head, as in *Disa atricapilla*, *D. melaleuca*, etc.

A **panicle** is a compound raceme, that is, one where each branch is itself branched, as in some Yuccas, Grape Vine, and Oats.

The **dichotomous cyme** (fig. 127) is one where two branches spring from beneath the terminal flower, each in its turn capped by a flower and developing two branches just below it, as in the Chickweed, Chironia, Crassula, and other plants of these orders.

If but one stalk be given off, which is again branched on the same side, and this again repeated a number of times always on the same side, so that the young flowers become

coiled like a scorpion's tail or a shepherd's crook, the **scorpioid cyme** is formed, as in the Forget-me-not, Aponogeton, and many of the Boraginaceæ (fig. 128).

The **verticillaster** consists of two cymose bunches placed on opposite sides of the stem, so as apparently to produce a whorl, as in *Leonotis* (fig. 257), and other members of the Labiataë.

Mixed Inflorescences.—Sometimes in a plant there is a



FIG. 127.—Dichotomous cyme of *Cerastium*.



FIG. 128.—Cymose inflorescence of *Myosotis*.

mixture of the two kinds of inflorescence. Thus in *Leonotis*, whilst each separate inflorescence is definite, being a verticillaster, yet, taking the whole plant, the arrangement is indefinite, the lower verticillasters opening first. On the other hand, in most of the members of the natural order Compositæ, whilst each capitulum is itself indefinite, yet, taking the plant as a whole, the arrangement is definite, for the terminal capitulum is the first to open.

Such an inflorescence is said to be mixed.

CHAPTER X.

STRUCTURE AND FUNCTIONS OF PARTS OF THE FLOWER.

THE flower is that part of the plant which subserves the purposes of reproduction.

When complete, the flower consists of four whorls or series of organs. The two outer ones are merely coverings, whilst the inner ones form the essential organs.

Commencing at the exterior, the outer coat is known as the **calyx** (fig. 129, K), and each division of which it is made up is a **sepal**. The inner coat is the **corolla**, and each separate part of it a **petal**.

The outermost whorl of the essential organs of the flower is the **androecium** (fig. 129, S), consisting of one or more **stamens**; whilst within there is the **pistil** or **gynœcium** (fig. 129, St), consisting of one or more **carpels**.

This will be a convenient place to note the distinction that is drawn between a complete and a perfect flower.

For a flower to be **complete**, all four of the whorls must be present; if any one be absent, the flower is **incomplete**. On the other hand, the term **perfect** is applied to all those flowers in which both androecium and pistil are present, although, as in the *Anemone* or *Protea* (figs. 207, 260), one of the coats may be wanting. An **imperfect** flower is one where there is only one whorl of the essential organs, as in the *Oak* or *Pumpkin*.

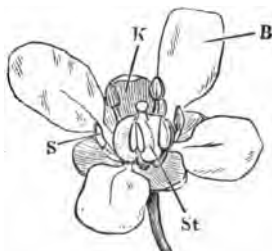


FIG. 129.—Flower of *Sisymbrium Alliaria*: K, calyx; B, corolla; S, stamens; St, pistil.

It follows that every complete flower must be perfect, but every perfect flower is not necessarily complete.

Perfect flowers are sometimes spoken of as **hermaphrodite**. Imperfect flowers are either **staminate** if the pistil be absent, or **pistillate** if the stamens be absent, e.g. *Cliffortia* (fig. 233).

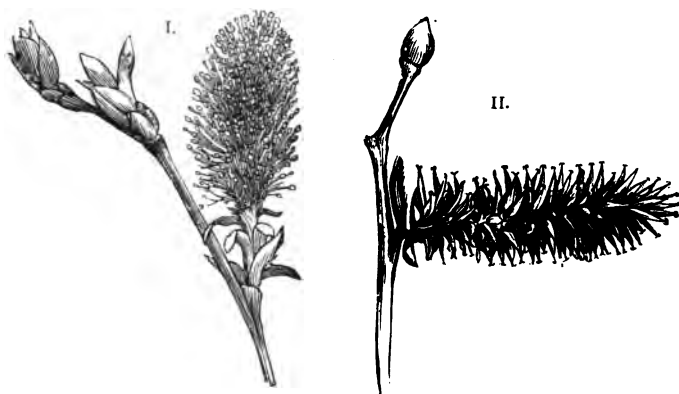


FIG. 130.—Sallow (*Salix caprea*). I. Male catkin. II. Female catkin.

If staminate and pistillate flowers grow upon the same plant, as in the Oak, Walnut, Pumpkin, the plant is said to be **monœcious**; if they grow upon separate plants, as in the Willow (fig. 130), Poplar, Yellow-wood, and Keiapple, it is **diœcious**; whilst if on the same plant are to be found hermaphrodite, staminate, and pistillate flowers, as in *Brabejum* (fig. 261), it is **polygamous**.



FIG. 131.—Flower of the Strawberry, with calyx in two rows.

We must now notice each part of the flower more particularly.

CALYX.—The sepals are generally arranged in one whorl, but in some cases, as in the Strawberry (fig. 131), there may be two (or even, as in the Cotton, three), whorls.

Generally the sepals are green, but sometimes, as in the Fuchsia, *Tropæolum*, *Polygala*, and some Heaths (e.g. *Erica elegans*), they are coloured, or petaloid.

When the calyx is inserted beneath the ovary upon the end

of the flower-stalk (which is known as the **thalamus**), it is said to be **inferior**, and the ovary is **superior**, as in the *Ranunculus* (fig. 205, and fig. 132, H and P).

In other cases the calyx is adherent to the sides of the

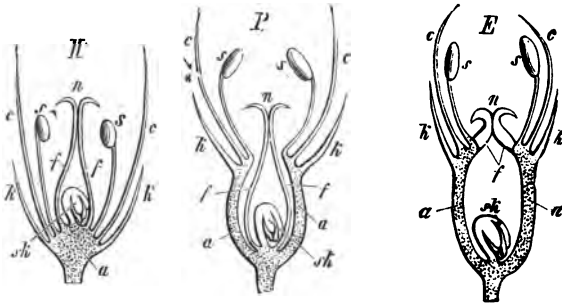


FIG. 132.—Diagrammatic section of hypogynous (H), perigynous (P), and epigynous (E) flowers. *a*, axis, forming convex or concave receptacle, or wall of ovary; *k*, calyx; *c*, corolla; *s*, stamens; *f*, carpels; *n*, stigma; *sk*, ovules. (After Prantl.)

ovary, only the free limb springing from its upper part (or the calyx springs entirely from the top of the ovary). It is then said to be **superior**, and the ovary is **inferior** (fig. 132, E), as in the *Fuchsia*, *Apple*, etc.



FIG. 133.—Spurred calyx of *Tropaeolum*.



FIG. 134.—Caducous calyx of *Poppy*.

When the sepals are distinct from one another, as in the *Strawberry* (fig. 131), it is said to be **polysepalous**. If the sepals be united together (fig. 136), the calyx is **gamosepalous**.

If, as in the Poppy (fig. 134), the calyx falls off as soon as the flower-bud opens, it is said to be **caducous**; if, as in the *Ranunculus* (fig. 205), it remains after the flower opens, but falls off before the fruit ripens, it is **deciduous**; whilst if it remains after the fruit has ripened, it is **persistent**, as in the Strawberry (fig. 131).

Sometimes the persistent calyx becomes very much enlarged around the fruit; it is then **accrescent**, as in *Physalis* and *Royena glabra*.

There are also certain terms which are used in describing the shape of the calyx which are of great importance in Descriptive Botany.

Such terms are: **regular** (fig. 136); **irregular** (fig. 133);

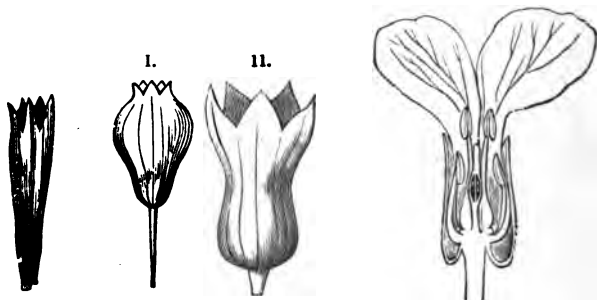


FIG. 135.—Tubular calyx.

FIG. 136.—I. Turbinate. II. Urceolate calyx (represented diagrammatically).

FIG. 137.—Saccate calyx of *Lunaria*.

tubular (fig. 135); **urceolate** (fig. 136, II.); **inflated** or **swollen**; **turbinate** (fig. 136, I.); **funnel-shaped** or **infundibuliform**; **saccate** (fig. 137), if there are four sepals, two of which are prolonged at the base, as in most cruciferous plants; **rotate** (fig. 131); **bilabiate** (fig. 257); **spurred** (figs. 133, 220); **galeate**, or **hooded**.

A remarkable form of calyx known as **pappus** is met with amongst the composites and some other flowers. In this case the sepals are converted into numerous hairs, which crown the ovary, and are often very much enlarged upon the fruit, as is seen in the head of the Dandelion after flowering.

The hairs may be either simple, when the pappus is **pilose** (fig. 138), or feathery (fig. 243).

In the Chicory the pappus is **coronate**, forming a crown of broad hairs above the fruit.

COROLLA.—The second enveloping coat of the flower is generally more delicate in its structure than the calyx, and is often highly coloured and possesses odour. If there be only one coat present, as in the Anemone and Clematis, whatever its appearance, it is spoken of as calyx.

The corolla is either **gamopetalous** or **polypetalous**—**regular** or **irregular**.

If the petals are attached with the calyx beneath the ovary



FIG. 138.—Pilose sessile pappus of *Senecio*.



FIG. 139.—Unguiculate petal of *Dianthus*, with toothed lamina.



FIG. 140.—Globose corolla of *Erica tetralix*.

(fig. 132, H), the corolla is said to be **hypogynous**; if the ovary be superior, but the petals, instead of being inserted under it, are attached upon the calyx, forming a ring round the ovary, the corolla is **perigynous** (fig. 132, P). When the ovary is inferior and the corolla springs from the top of it with the calyx (fig. 132, E), it is **epigynous**.

The corolla rarely remains to form a part of the fruit, as the calyx does sometimes.

Terms are also employed to describe the shape of the corolla, and of the individual petals.

When the petals are broad above and form a narrow limb below, as in the Pink (fig. 139), they are said to be **unguiculate** or **clawed**.

Again, the corolla may be **tubular** (fig. 253); **campanulate** or bell-shaped (fig. 251); **urceolate** or urn-shaped; **globose**, as in many Heaths; **infundibuliform** or funnel-shaped (fig. 240); **rotate** or wheel-shaped (fig. 141); **cruciform** or cross-shaped, when there are four petals arranged like a Maltese cross (fig. 208); **ligulate** or strap-shaped, when the lower part of the corolla forms a tube and the upper part is flattened out, as in the ray florets of the Daisy and florets of the Dandelion (fig.



FIG. 141.—Rotate corolla of the Borage (*Borago officinalis*).

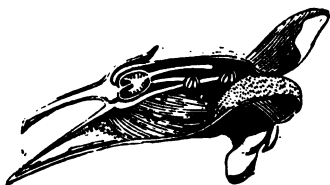


FIG. 142.—Bilabiate personate corolla of *Antirrhinum majus*.

247); **spurred**, as in the Violet and many Orchids; **bilabiate** or two-lipped. Of this there are two forms: if the lips are wide apart, as in *Leonotis* (fig. 257), it is **ringent**; if closed, as in the Snapdragon (fig. 142), it is **personate**. In *Erythrina* and other members of the Pea-flower tribe it is **papilionaceous** or butterfly-shaped (fig. 224). In this case there are five petals, one overlooking the rest, the *standard* or *vexillum*; one standing out on each side, the *wings* or *alæ*; and two united surrounding the stamens, the *keel* or *carina*.



FIG. 143.—Petaloid perianth of *Narcissus*, with 6-partite limb and campanulate corona.

There are sometimes attached to the corolla subsidiary organs, which are variously arranged, and which, owing to their not being universally present, are not treated of as separate organs. They form the **corona** or **paracorolla**, and are petaloid, and well developed in the *Narcissus* (fig. 143) and many *Asclepiadaceæ*, e.g. *Gomphocarpus*; or small, as in the *Lychnis* (fig. 213) and many

Apocynaceæ, *e.g.* Oleander ; or consist of hairs, as in the Passion-flower, or of scales.

NECTARIES, or glands for the secretion of honey, are sometimes spoken of as subsidiary organs, but various parts of the flower may be specially developed for this function. Thus, there may be scales between the stamens, as in the Grape Vine (fig. 144) ; or spurs, either of the calyx as in the *Tropæolum* and *Pelargonium* (figs. 133, 220), or of the corolla as in *Nemesia*, or of both as in the Larkspur ; or of the stamens as in the Violet (fig. 145) ; or there may be glands in hollows at



FIG. 144.—Stamens and pistil of the Grape Vine, with a honey gland (nectary) between each pair of stamens.



FIG. 145.—Spurred stamens of Violet.

the base of the petals, as in the Buttercup ; or a honey-secreting disc, as in *Melianthus*.

ÆSTIVATION.—Just as the terms *vernation* and *præfoliation* are applied to the arrangement of the foliage leaves in the bud, so the terms *æstivation* and *præfloration* are employed to describe the arrangement of the leaves in the flower-bud.

ANDRŒCIUM.—We now come to the first whorl of the essential organs of the flower. Each **stamen** of which the andrœcium is composed consists, when complete, of **three parts**, *viz.* the stalk which attaches it to the rest of the flower, and which is known as the **filament** ; the knob on the summit, which is in reality a little box, the **anther** ; and within this a fine powder, the **pollen**, which is the essential part of the stamen.

These stamens may be either distinct, when they are said

to be **free**, as in the *Ranunculus* (figs. 205, 207), or they are more or less united.

If they are united by means of their filaments into one bundle, whilst their anthers are free, as in the Mallow (fig. 146), they are said to be **monadelphous**.

If there be two bundles, as in the Sweet-pea (fig. 147), the androecium is **diadelphous**; and if more than two bundles, as in the Orange (fig. 148), **polyadelphous**. If the stamens are attached together by means of their anthers, whilst the filaments are free, as in the Thistle and other composite plants (fig. 149),



FIG. 146.—Monadelphous stamens of *Malva*.



FIG. 147.—Diadelphous stamens of *Lathyrus*; nine filaments united into a sheath at the base, one free.



FIG. 148.—Polyadelphous stamens of Orange.

and *Lobelia* (fig. 252), they are **syngenesious**. If the anthers are attached immediately upon the pistil, as in the *Asclepiads* and various *Orchids*, they are **gynandrous**.

With regard to the attachments of the stamens, we apply the same terms which we used in describing the position of the corolla. Thus the stamens may be **hypogynous** (fig. 132, H), **perigynous**, or **epigynous**. In addition to these positions, the stamens may be upon the corolla, when they are said to be **epipetalous**, as in the *Honeysuckle* (fig. 150). If the filament of the stamens be absent, as in the *Verbena* (fig. 212) and *Protea*, the anthers are said to be **sessile**.

More often there is a filament present which is generally thin and thread-like, but sometimes, as in some of the stamens of the *Water-lily*, it is broad and flat. Generally the various

filaments are about the same length, but in some cases there is a constant difference between the stamens on this point. Thus



FIG. 149.—Syngenesious anthers of Thistle; the filaments free.

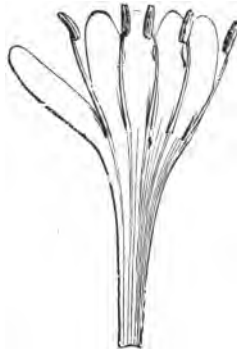


FIG. 150.—Section of corolla of Honeysuckle, with epipetalous stamens.

in the Mustard (fig. 209), and allied plants of the natural order Cruciferae, there are four long and two short stamens, when



FIG. 151.—Section of corolla of *Verbena*, with sessile epipetalous anthers.



FIG. 152.—Stamen of Wheat, with versatile anther, *b*, lightly fixed at the extremity of the filament, *a*.

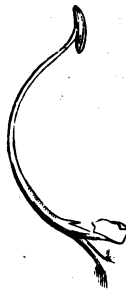


FIG. 153.—Stamen of *Salvia*, with connective branching into two arms of very unequal length, the right-hand arm bearing an abortive anther.

they are said to be **tetradynamous**; whilst in most plants of the order Labiatae there are two long and two short, and the stamens are **didynamous** (fig. 257).

If the **anthers** are attached immediately upon the top of the filaments, they are said to be **innate**, or **basifixed**. If the filament is prolonged up behind the anthers, they are **adnate** or **dorsifixed** (fig. 259); and if it be attached loosely to the centres of the anthers, so that they swing upon the point of attachment, as in the Wheat (fig. 152), they are **versatile**.

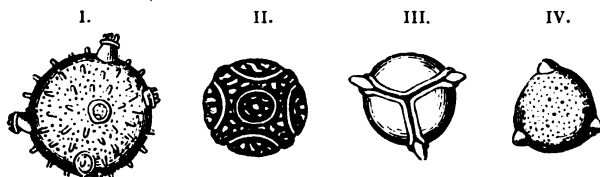
The portion of the filament to which the anthers are attached is called the **connective**. In the Sage (fig. 153) the connective is divided into unequal branches; the long one bears a perfect anther lobe, whilst the short one has an abortive anther, or one destitute of pollen.

The anther lobes are hollow, possessing cells or loculi, of which there is generally one for each lobe, so that the anther is two-celled or **bilocular**. In the early stage of its development there are four cells, two in each lobe; but generally the partition between the loculi in each anther lobe is absorbed, producing the bilocular anther. In some plants, as in *Seidelia* (Urticaceæ), this division never disappears, and the anther remains four-celled. In some few plants, as the *Harveya* (fig. 255) and *Restio* (fig. 276), there is but one cell, and the anther is then said to be **unilocular**.

The surface of the anther to which the connective is attached is known as its **back**, whilst the other side is called the **face**. This is generally grooved, showing the point of attachment of the lobes. When the face is turned towards the pistil, the stamens are said to be **introrse**; when towards the petals, **extrorse**.

Within the anther lobes there are developed the **pollen grains** (fig. 154). In the early stages of the growth of the anthers there are a large number of cells forming the central part of each lobe. These are the *parent* or *mother cells* of the pollen grains. Each of these, by cell division, becomes divided into four *special parent cells*, and in each, by a process known as free cell-formation, a pollen grain is formed. In free cell-formation the protoplasm aggregates around the nucleus of the mother cell, a cellulose coat is formed around it, and thus for a while we have a cell within a cell. As the pollen grains grow the walls of the special mother cells and mother cells generally

become absorbed and disappear, and the grains thus become loose in the cavity of the lobe. Sometimes, however, the wall of the special parent cells is not quite absorbed, and there is formed a component body of four pollen cells united, as in *Mimoseæ*, whilst in the *Orchids* and *Asclepiadaceæ* the pollen cells of each lobe are completely united together, forming a pollen mass or **pollinium** (fig. 154, v). Each pollen



grain possesses two coats: the inner one, the **intine**, is complete; the outer one, the **extine**, is pierced by several openings, and is often variously ornamented by spines, protuberances, or reticulations (see fig. 154). In form the pollen granules are generally round; in the *Chicory* they are polyhedral; in the *Evening Primrose* (*Cenothera*), triangular; in the *Tradescantia*, cylindrical; and in the *Zostera*, thread-like.

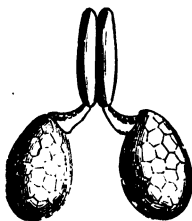


FIG. 154. — Pollen grains.
I. *Cucurbita*. II. *Passiflora*. III. *Cuphea platycentra*. IV. *Dipsacus fullonum*. V. Pollen-masses (pollinia) of *Cynanchum Vincetoxicum* (Asclepiadaceæ).

FIG. 154 A. — *Mystropteron Thomii*. Pollen grain.

When the pollen is ripe, the anther lobes open to let it fall out. They open or dehisce in various ways.

1. *Longitudinal dehiscence*, as in the *Pine* (fig. 155) or *Gladiolus*, when there is a slit running along the face of the anther from top to bottom. This is the commonest form.

2. *Transverse dehiscence*, in *Alchemilla* and several *Scrophulariaceæ*.

3. *Porous dehiscence*, openings being produced either at the apex of the lobe, as in the *Rhododendron* (fig. 156); or in the side, as in the *Heath* (fig. 254).

4. *Valvular dehiscence*, when a portion of the anther lobe

lifts up like a trap-door, as in the Laurel (fig. 157), Camphor-tree, and Cassytha.

GYNÆCIUM OR PISTIL.—Each of the **carpels** of which the pistil is made up consists, when complete, of a swollen basal portion, the **ovary**; above this a stalk or **style**, which is capped by the **stigma**. The ovary is a hollow box containing one or more rounded bodies, the **ovules**. Generally the carpels of the pistil are united together, either entirely, as in the Lily (fig. 158), or, as is often the case, the ovaries are united whilst the styles and stigmas are free, as in *Statice* (fig. 159). In these cases



FIG. 155.—Stamen of *Pinus sylvestris*, with longitudinal dehiscence.



FIG. 156.—Stamen of *Rhododendron*, each anther-lobe opening by a pore.



FIG. 157.—Stamen of Bay (*Laurus nobilis*), with two glands at the base of the filament, the anther opening by recurved valves.



FIG. 158.—Pistil of Lily, with ovary, style, and stigma.

the pistil is said to be **syncarpous**. When the ovaries are distinct, as in the Ranunculaceæ or Magnolia (fig. 205), it is **apocarpous** (when there is only one carpel to the pistil, as in the case of the Pea, it is also said to be **apocarpous**). If there is but one carpel, the pistil is said to be **monocarpellary**. A **bicarpellary** pistil has two carpels, a **tricarpellary** three, a **polycarpellary** pistil more than three.

In a syncarpous pistil we can often tell the number of carpels present by the separate stigmas (or styles) (fig. 159). In other cases we find on making a section that the syncarpous ovary possesses several cells or loculi, each corresponding with

a single carpel, so that from them we can count the number of carpels (fig. 160). Sometimes we find that there is but a single loculus in the ovary, and we can then often tell the number of carpels by noticing in how many places the ovules are arranged (fig. 161).

The ovary, as we have seen, may be either *inferior* or *superior*. In the former case, it is either inserted in the fleshy end of the flower-stalk, known as the *thalamus* or *receptacle*, so that the calyx springs from above it; or the calyx tube is adherent to the wall of the ovary, the free limb springing from the top. We often find two lines running down the ovary from apex to base. These are known as the *sutures*: the one to-



FIG. 159.—Papillose stigma of *Statica*.

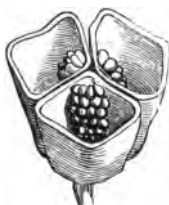


FIG. 160.—Capsule of *Colchicum*; transverse section.



FIG. 161.—Section of ovary of *Viola*.

wards the centre of the flower is the *ventral suture*, whilst the one turned towards the perianth is the *dorsal suture*.

When the pistil is apocarpous, each ovary contains but one cell, or is **unilocular**, although sometimes there are false partitions growing partially across the cell.

In syncarpous ovaries there are often numerous cells agreeing with the numbers of the carpels (fig. 162, D), when the ovary is **bi-**, **tri-**, or **multi-locular**. In other cases there is but one cell, the ovary being **unilocular**. Sometimes there are partial dissepiments formed by an infolding of the edges of the carpels. In some few cases there are actual divisions; thus the ovary of the Labiatae and Boraginaceae is originally bilocular.

but by a subsequent division it becomes divided into four cells. The ovules are not, as a rule, distributed indiscriminately over the surface of the ovary, but are arranged on certain parts of the wall, each of which is called a **placenta**, whilst the arrangement of the ovules is spoken of as **placentation**.

In the case of apocarpous pistils, where there are more than one ovule, they are generally arranged along the ventral

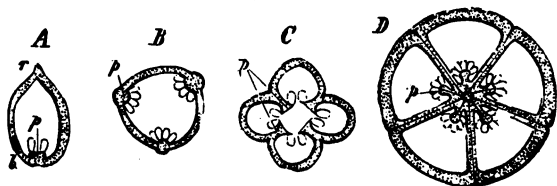


FIG. 162.—Diagrammatic sections of ovaries: *p*, the placenta, to which the seeds are attached; *A*, monocarpellary unilocular; *B*, polycarpellary unilocular; *C*, polycarpellary falsely multilocular; *D*, polycarpellary multilocular; *r*, dorsal suture, or midrib; *b*, ventral suture, or margins of carpel. (After Prantl.)

suture, and the placentation is said to be **marginal** (figs. 163 and 162, *A*). In the multilocular syncarpous pistil the ovules are generally arranged in the central axis, where the cells of the ovary meet (fig. 162, *D*), and the placentation is **axile**.

When the ovary is unilocular the ovules are arranged either upon the wall (fig. 162, *B*), or upon slight projections (fig. 162, *C*), and the placentation is **parietal**.

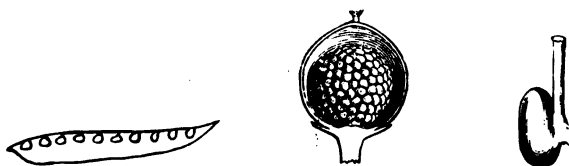


FIG. 163.—Marginal placentation.

FIG. 164.—Unilocular ovary, with free central placenta.

FIG. 165.—Lateral style of Strawberry.

In some cases of a unilocular ovary, as in the Primrose and Pink, the ovules are attached to the end of the flower-stalk, which grows up into the ovary (fig. 164). This is called **free central placentation**.

The **style**, when present, forms a conducting tube from the stigma to the ovary. In the Violet it consists of a perfectly

hollow tube, but generally its centre is filled with loose "conducting tissue." Very often the style is absent, in which case the stigma is said to be *sessile* upon the ovary.

The **stigma** is intended to receive the pollen grains, and hence its presence is necessary in the perfect pistil. It varies much in appearance. In some cases it is merely an opening at the top of the style, upon which is secreted some glutinous fluid. In other cases it is variously enlarged. It is **capitate** in the Lily (fig. 158); **petaloid** in *Moræa* (fig. 270); **penicillate**



FIG. 166.—Pistil of *Parietaria*, with penicillate stigma.



FIG. 167.—Peltate Stigma of Poppy, with hypogynous stamen.

in the Pellitory of the Wall (fig. 166); **peltate**, or shield-like, in the Poppy (fig. 167).

The **ovule**, when in a young state, consists simply of a mass of parenchymatous cells; these soon become surrounded by coats, the **primine** (*ai*, fig. 168) and the **secundine**. These coats are not complete, leaving an opening, the **micropyle**, leading into the interior of the ovule, which is composed of the original cellular mass forming the **nucleus** (*k*), amongst which is one cell, the **embryo-sac** (*em*), larger than the rest.

The ovule is generally attached to the placenta by a short stalk, the **funiculus** (*f*). The point by which the ovule is attached to the funiculus (or placenta) is the **hilum**, whilst the point by which the nucleus is attached to the integuments is the **chalaza** (*c*).

There are three forms of ovules, differing in the arrangement of their parts:—

Orthotropous ovule (fig. 168, A). In this case the nucleus

is straight, the chalaza and hilum are in proximity, and the micropyle is removed to a distance from the funiculus. This form is rare, being met with in the Rhubarb, Buckwheat, and their allies in the natural order Polygonaceæ.

Anatropous ovule (fig. 168, B). In this case the nucleus is straight, but is inverted upon the funiculus, so that the micropyle is brought down into close proximity with the stalk, whilst the hilum and chalaza are separated, being united by a prolongation of the funiculus known as the *raphe*. This form is well seen in the Dandelion and Water-lily.

Campylotropous or bent ovule (fig. 168, C). In this case the nucleus is bent, so that whilst the micropyle is brought near

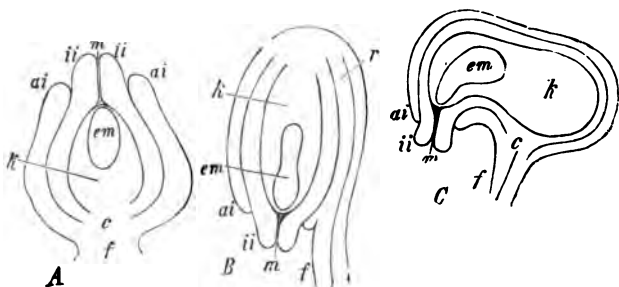


FIG. 168.—Diagrammatic longitudinal sections of ovules: A, orthotropous or straight; B, anatropous or inverted; and C, campylotropous or bent ovule. *ai*, Outer integument or primine; *ii*, inner integument or secundine; *m*, the micropyle; *k*, the nucleus, with the embryo-sac, *em*; *c*, the chalaza or base of the nucleus; *f*, the funiculus; *r*, the raphe of the anatropal ovule, formed by the fusion of the outer integument and funiculus. (After Prantl.)

the funiculus, as in the anatropous form, the chalaza and hilum are in close proximity as in the orthotropous form, and there is no need of a raphe. The Wallflower and Mallow are examples of this kind. These three forms are united by many modifications.

Thalamus and Disc.—The thalamus, or end of the flower-stalk upon which the various floral organs are inserted, is often specially modified. Thus in all plants with a free central placentation it is prolonged into the ovary, bearing the ovules. In other cases, as in the Umbelliferae and Geraniaceæ, it is prolonged between the carpels and beyond the ovary, and is known as the **carpophore** (see p. 149).

In other cases, as in the Pink, Passion-flower, and Capparidaceæ, it is prolonged beyond the calyx, forming a stalk for the ovary (figs. 169, 170), and it is known as the **gynophore**. In many plants it is much swollen, and the ovaries are sunk or embedded in it, often giving them a syncarpous appearance when they are truly apocarpous.

We sometimes find between the calyx and pistil a body or bodies which are not universal among flowers, and which cannot be referred to any of the organs above described. To this body the name of **disc** is applied. In the Mignonette and Orange it forms a fleshy swelling below the pistil; in

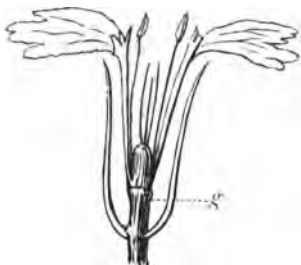


FIG. 169.—Section of *Lychnis Flos-Jovis*, with gynophore, *g*.

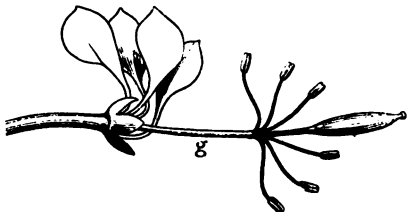


FIG. 170.—*Gynandropsis pentaphylla*. Flower with large gynophore, *g*.

umbelliferous plants it surmounts the ovary, adhering to the styles. In other cases it is variously developed (fig. 222).

Cohesion and Adhesion.—When the similar parts of a flower are united together in growth, we speak of it as **cohesion**; when dissimilar parts are united, as **adhesion**. Thus the formation of a gamosepalous calyx, a gamopetalous corolla, or of monadelphous stamens would be cohesion; whilst the growth of the calyx to the ovary, or the epipetalous or gynandrous arrangement of stamens, would be due to adhesion.

It will often give an idea of how the parts of a flower are arranged with regard to cohesion and adhesion to make a floral diagram of it (see figs. 224, 228, 230, and footnote on p. 137).

Fertilization.—In order that the ovary and ovules may properly perform their functions, it is necessary that they should be fertilized by the pollen. The pollen grains adhere

to the stigma (fig. 171, *b*), and being nourished by the viscid secretion present, a portion of the intine protrudes either through an opening already existing in the extine, or forcing its way through a part where the outer wall is thinner. The prolongation thus formed is known as a **pollen-tube** (fig. 172). These tubes grow down the loose conducting tissue of the style and enter the ovary.

The time necessary for this varies from a few hours to several weeks. In the *Crocus* it takes from twenty-four to seventy-two hours; in the *Arum* over five days, and in the *Orchids* even some months.

Just previous to this, or about the same time, a change has been going on in the embryo-sac of the ovule, which, among others, caused the formation of two embryonic vesicles.

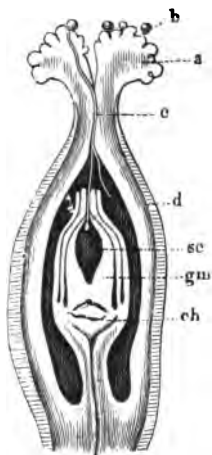


FIG. 171. — Longitudinal section through the uniovular ovary of *Polygonum Convolvulus* at the time of flowering: *a*, stigma; *b*, pollen grains; *c*, pollen-tube; *d*, wall of the ovary; *gm*, the erect orthotropous ovule; *se*, its embryo-sac; *ch*, chalaza: two pollen-tubes have penetrated through the conducting tissue of the style, one of which has entered the micropyle of the ovule, the other not.

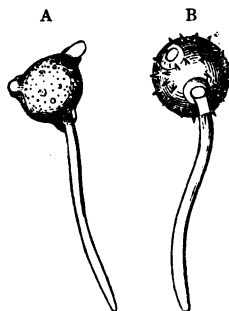


FIG. 172.—Pollen grains putting out their pollen-tube: *A*, *Dipsacus fullonum*; *B*, *Cucurbita*.

The pollen tube passing into the ovary enters the micropyle of one of the ovules, and, arriving at the apex of the embryo-sac, comes in contact with one of the embryonic vesicles, and fertilizes it. The fertilized vesicle then develops the embryo, while a number of cells are produced within the embryo-sac by free cell-formation (fig. 173). These become filled with

nutritive materials, and are known as **endosperm**. Sometimes such nutritive cells are produced within the nucleus outside the embryo-sac. In this case the term **perisperm** is employed.

In the fertilization of the Fir trees and their allies there is a modification of this process. The ovules, instead of being enclosed in an ovary, are naked (whence the plants are said to

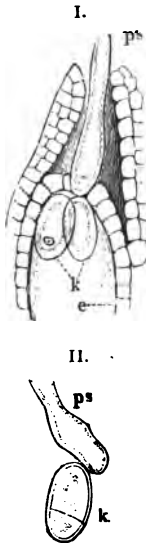


FIG. 173.—Fertilization of *Canna*. I. Apex of the embryo-sac, *e*, at the time when the pollen-tube, *ps*, has just come into contact with the embryonic vesicle, *k*. II. Fertilized embryonic vesicle separated.

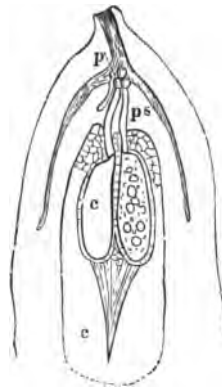


FIG. 174.—Section through ovule of *Abies excelsa* during fertilization; *p*, pollen grains; *ps*, pollen-tubes; *c*, two corpuscles in the embryo-sac, *e*.

be **gymnosperms**, or naked-seeded plants, whilst other flowering plants are **angiosperms**, or enclosed-seeded plants), so that the pollen falls direct upon the micropyle (fig. 174).

The embryo-sac, after pollination, is filled with endosperm, in which some cells enlarge, forming the **corpuscula**. One of these enlarges further, developing into what is called the **oosphere**. The pollen tube grows down into the oosphere and fertilizes it, whereupon a portion of the oosphere is developed into the embryo.

As a general rule the pollen is not capable of fertilizing the ovules of the *same* flower, and hence has to be taken to another, and the process known as **cross-fertilization** is brought about. The pollen is carried from flower to flower by various means. The first agency we shall notice is the wind. In the Oak, for example, we have a monoëcious plant with unisexual flowers. It is evident that the pollen must be transferred from one flower to another. The male and female catkins are on the same plant (fig. 264), the former pendulous with numerous anthers and a large quantity of pollen, the latter erect with the stigmas appearing through the enveloping bracts. When the pollen is fully ripe, it is shed from the anther cells and scattered by the wind; the greater portion is wasted, but some falls upon the stigmas, fertilizing them. Such a plant is said to be **anemophilous**, or wind-fertilized. Other examples of anemophilous plants are to be found in the Willow, the Fir, the Yellow-wood, and various Grasses and Cereals. In all these cases the flowers are small and inconspicuous and destitute of odour, whilst the pollen is produced in a far larger quantity than is actually needed for fertilizing purposes. Often in Pine forests the pollen is given off into the air in such enormous quantities that it is washed down by the rain as a yellow powder, and is popularly known as *sulphur rain*.

More important agents in the fertilization of flowers are insects and birds. In all cases of insect-fertilized (**entomophilous**) and bird-fertilized (**ornithophilous**) plants the flowers possess either rich and variegated colours, or sweet odours, or have both qualities. These serve to attract the insect or bird, whilst in some part of the flower honey is stored up in a nectary. Whilst endeavouring to obtain this, the animal comes into contact with the anther, and the pollen is scattered over portions of its body, and, being carried away, adheres to the glutinous stigma of the next flower visited.

The mechanical contrivances and arrangements to ensure this proper distribution of the pollen are very numerous. In an elementary book such as this it is only possible to notice a few typical forms.

In many cases it is impossible for the flowers to be self-

fertilized, as either the anthers are ripened before the stigmas, or the stigmas before the anthers. This is known as **dichogamy**, and in the former case the flower is **protandrous**, and

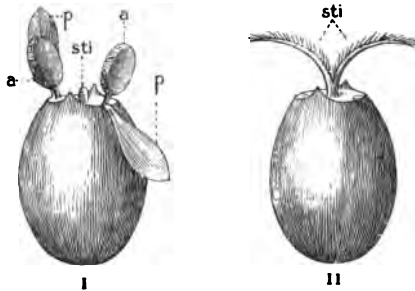


FIG. 175.—*Gunnera perperna*. Protandrous flower. I. First stage: *p*, petals (one pressed down); *a*, anthers; *sti*, stigmas. II. Second stage. Stigmas developed (magnified).

the pollen has to fertilize the pistil of a flower which preceded it in opening; whilst in the latter case the flowers are **protogynous**, and the pollen fertilizes a later flower.

A good example of a protandrous plant, and one which at the same time shows mechanical arrangements for ensuring the delivery of the pollen upon the right part of the insect's body, is to be found in the Sage. Fig. 176 shows in diagrammatic form the arrangement of the parts in *Salvia*. The corolla is

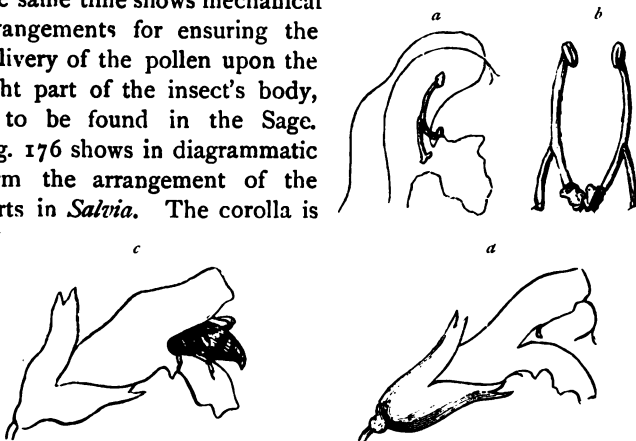


FIG. 176.—Sage fertilization.

bilabiate, the lower lip forming a convenient resting-place for

the insect to stand upon, whilst the upper lip protects the stamens and pistil from the rain.

The stamens, two in number, have branched connectives ; the lower lobes are abortive and united together (*b*), so that if either be pushed it affects both stamens. The upper lobe is full of pollen, and is poised upon the movable connective in such a manner that if the abortive lobes are pushed backwards and upwards the upper ones come downwards and forwards. In the corolla tube honey is secreted. The style and stigmas at first are placed well back against the upper lip, and are not matured until after the pollen. When they are matured, however, the style bends forward (*d*), bringing the stigmas near the centre of the mouth. If a bee visits one of the flowers which has its pollen matured, in order to seek for honey, it will, on entering the flower and plunging its proboscis into the tube, strike its head against the lower anther lobes, bringing the fertile lobes down against its sides, covering its body with pollen (*c*).

If it now visits another flower in the same condition, it will simply have its stock of pollen increased ; but if it visits a flower which has its pistil bent over, evidently the stigmas will strike against the insect's back, and some of the pollen scattered there will adhere to the glutinous stigmatic surface.

Other protandrous flowers are met with in the *Pelargonium* (fig. 220), *Campanulaceæ* (fig. 251), the Pinks and other members of the *Caryophyllææ*, many *Compositæ*, *Umbelliferæ*, *Proteaceæ*, etc.

Protogynous flowers are much less common, but they are met with amongst the *Magnolias*, *Plantago*, and other species of plants.

Another arrangement is known under the name of **heterostylism**, where the pistils and stamens of different flowers are of various lengths. A good example of a heterostylic flower is to be found in the Primrose. If we examine a number of Primroses we shall find the flowers of two different kinds. Some have a little knob filling up the mouth of the corolla tube, and others a rosette. On making a vertical section of one of each kind of flower, we find the arrangement as shown

in fig. 177. In the first case we have the pistil with a long style, whilst the stamens are placed low down in the tube. In the other case the stamens are high up, whilst the style is short and the stigma at about the same height as the stamens in the preceding variety. Such a flower is said to be **dimorphic**, and we can speak of the "long-styled" and "short-styled" varieties of Primrose. There is a slight difference in the pollen and the stigmas in the two cases. The pollen grains of the short-styled flowers are larger than those of the long-styled flowers, and the stigma in the latter case is globular, whilst in the former it is depressed in the centre. A number

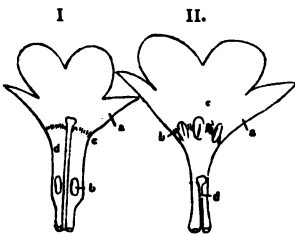


FIG. 177.—Dimorphic flower of *Primula*. I. Long-styled, II. Short-styled form: *a*, corolla; *b*, anthers; *c*, ring of hairs; *d*, pistil.

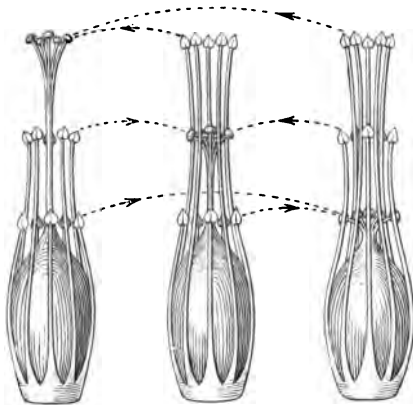


FIG. 178.—Trimorphic flowers of *Oxalis cernua*. The arrows indicate the legitimate combinations.

of careful experiments by Professor Darwin and others show that long-styled flowers are fertilized by the pollen from short-styled, and *vice versa* the short-styled are fertilized by the pollen from the long-styled. Such a cross Mr. Darwin calls *legitimate union*, whilst the term *illegitimate union* is applied to the union of long-styled pollen with long-styled stigma. This illegitimate union will not produce seeds to the extent that the legitimate will, and in some dimorphic flowers none at all are formed.

In the many species of *Oxalis* we have **trimorphic** flowers: one with long style, five medium stamens, and five short

stamens; one with medium style, five long stamens, and five short stamens; and one with short style, five long stamens, and five medium stamens. In such cases we always find that the long style is fertilized by the long stamens, the medium style by the medium stamens, and the short style by the short stamens, as shown by the lines in the diagram.

Whilst these provisions for cross-fertilization are the rule amongst flowers, in some few cases there is a special arrangement for self-fertilization. The Sweet Violet is a good example. The well-known flowers that appear in the spring do not, although fertilized by insects, bear fruit. They are followed in the summer by small inconspicuous apetalous flowers, where the stamens and pistil are enclosed in a calyx which does not open. The result is, the flowers are fertilized by their own stamens. Such flowers are said to be **cleistogamous**. Besides this there are other examples where self-fertilization is specially provided for.

RELATION OF FLOWER TO OTHER PARTS OF THE PLANT.

The parts of the flower must be looked upon as modified foliar organs. This is pretty evident in the calyx and corolla, but not so well seen at first in the stamens. We have proof, however, in the facts, (1) of the tendency in double flowers to form petals instead of stamens; and (2) the gradual transition

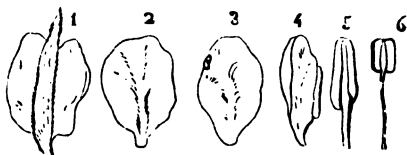


FIG. 179.—Stages of transition between the petals and stamens of *Rosa centifolia*.

from petals to stamens, as seen in the Water-lily, or *Rosa centifolia* (fig. 179).

In some cases the filament appears to represent the petiole, the connective the midrib, and the anther the blade, when the pollen would represent the general internal tissue of the leaf.

In other cases the filament appears to be the leaf-blade, and the anthers and pollen appendages upon it.

We must regard the carpels as leaves (carpellary leaves), either folded over so that their edges meet, when the dorsal suture marks the midrib, and the ventral the margin of the leaves, or, in a unilocular polycarpellary pistil, the carpellary leaves unite by their margins. The placenta is developed on the margin of the carpellary leaves, or, in the free central placentation, on the prolongation of the stem. The ovules are appendages of the carpellary leaves, or, in the case of the free central placentation, buds upon the prolonged axis.

CHAPTER XI.

FRUIT AND SEED.

AFTER fertilization a change takes place in the ovary ; it enlarges and changes very much in appearance, forming the fruit. Botanically the **fruit** is the **ripened ovary**. Many so-called fruits, however, have in addition to the ovary some other part of the flower attached. Thus, in the Strawberry and Apple, the fleshy edible part is the enlarged receptacle or **thalamus**, the pips of the Strawberry and the core of the Apple being the

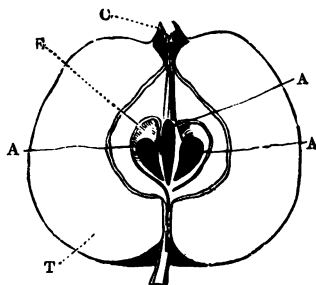


FIG. 180. — Longitudinal section through an Apple: c, dry persistent calyx limb; E, loculi with cartilaginous pericarp; T, mesocarp.



FIG. 181. — Multiple pseudocarp of the Mulberry.

true fruits. In these cases the term **pseudocarp** is applied, whilst if we have a whole inflorescence forming a fruit-like mass, with the bracts or any other part of the floral organs added, as in the Pineapple and Mulberry, the term **pseudosyncarp** is employed (fig. 181).

The walls of the ovary consist of three layers : hence in the fruit we find three layers present—the outer or **epicarp**, the middle or **mesocarp**, and the inner or **endocarp**. Often these

three layers cannot easily be distinguished from one another ; at other times they are very evident. The number of cavities or loculi in the fruit generally corresponds to that in the ovary ; sometimes, however, some of the partitions disappear, so that the fruit possesses fewer loculi than the ovary.

We may divide fruits into those which are **dehiscent** or break, and those which are **indehiscent** or do not break, when ripe.

DEHISCENT FRUITS.

When a dehiscent fruit opens so that the seeds fall out, it is known as a **capsule**. The dehiscence may take place longi-



FIG. 182.—Capsule of *Primula* dehiscing by ten teeth.



FIG. 183.—Capsule or pyxis of *Anagallis*, with circumscissile dehiscence.



FIG. 184.—Capsule of Poppy dehiscing by pores beneath the peltate stigma.

tudinally or from top to bottom of the fruit, breaking it into several valves ; it is then said to be *valvular*. Or it may take place in a transverse manner, opening off like a lid, when it is

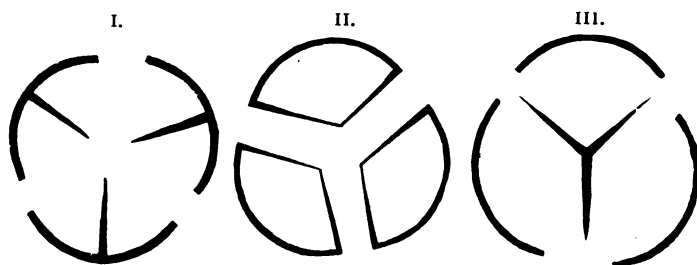


FIG. 185.—I. Diagram of a loculicidal capsule. II. Diagram of a septicidal capsules. III. Diagram of a septicidal capsule.

described as *transverse* or *circumscissile* dehiscence (fig. 183). Or, lastly, there may be small openings or pores, when the dehiscence is *porous* (fig. 184).

If the longitudinal dehiscence is partial, so as to only take place at the top of the fruit by means of a number of teeth, it is *dehiscent by teeth* (fig. 182).

If the dehiscence is complete, it may either take place by the ventral suture, or by the dorsal suture, or by both. Again, in some cases the walls of the loculi split open, leaving the septa attached to them, as in the Lily and Irideæ; the dehiscence is then said to be *loculicidal*. It is *septicidal* when

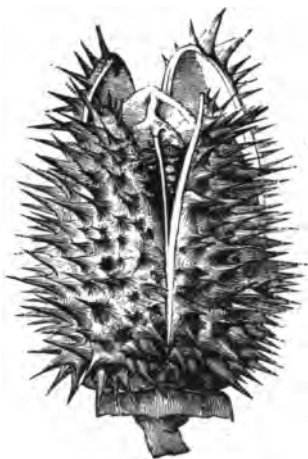


FIG. 186.—Septifragal capsule of *Datura*.



FIG. 187.—Fruit of *Illicium* or Star-Anise, consisting of a number of follicles.

the fruit breaks up into its separate carpels, the dehiscence taking place down the septa themselves, as in *Baomitra* and other Melanthaceæ; and it is *septifragal* when, the carpels opening by their dorsal sutures, the dissepiments separate from the valves, being still attached in the centre, as in the Thorn-apple (see figs. 185 and 186).

Some forms of capsules have received special names.

A **legume**, or **pod**, is a unilocular monocarpellary capsule dehiscing by both dorsal and ventral sutures, as in the Pea (fig. 226).

A **follicle** is a monocarpellary capsule dehiscing by ventral suture (fig. 187), or, in some Magnolias, by dorsal suture, only.

A **siliqua** is a syncarpous bicarpellary capsule, one-celled, with a false division or **replum** running up the centre. It is long and narrow in shape, and the two side walls break away,



FIG. 188. — Septicidal capsules of *Boerhaavia columellaris*, Sal.

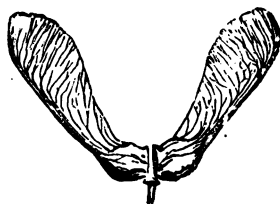


FIG. 189. — Schizocarp of the Maple, consisting of two samaras.

leaving the central replum with seeds. An example is seen in the fruit of the Wallflower (fig. 210).

A **silicula** resembles the last, except that, instead of being long and narrow, it is short and broad (fig. 211).

When a dehiscent fruit breaks up into several portions which are usually one-seeded and remain closed, although they do in some few cases open to allow the seeds to fall out, it is called a **schizocarp**, the divisions being called **mericarps**.

The number of mericarps may be two, *e.g.* Umbelliferae (fig. 237); or three, *e.g.* Indian Cress (fig. 190); or four, *e.g.* Labiatae (fig. 257); or five, *e.g.* Pelargonium (fig. 221); or many (fig. 218).

A **samara** is a winged fruit: in some cases, as in the Maple

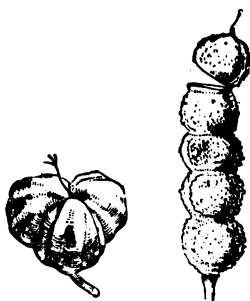


FIG. 190. — Tripartite schizocarp of *Tropaeolum*.

FIG. 191. — Lomentum of *Hedysarum*.

(fig. 189), the fruit consists of two samaræ; in other cases, e.g. *Acridocarpus*, of three or four.

A **lomentum** is a pod or a siliqua dehiscing transversely into two or more one-seeded portions, as in the *Desmodium* and the Radish (fig. 212).

INDEHISCENT FRUITS

The **drupe**, or **stone fruit**. In this case the three layers of the fruit are always distinct. The endocarp is hard, forming the so-called stone. The epicarp and mesocarp differ in their



FIG. 192.—Longitudinal section through the unilocular drupe of the Peach.

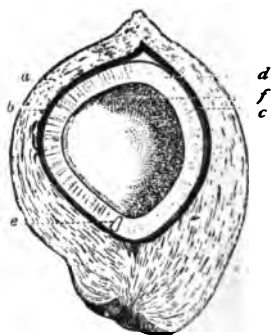


FIG. 193.—Longitudinal section of Coconut: *a*, epicarp; *b*, endocarp; *c*, testa; *d*, endosperm or albumen; *e*, embryo; *f*, cavity in the endosperm which contains the milk.

consistency. In the Plum, Cherry, and Peach (fig. 192) the epicarp forms the skin, and the mesocarp the succulent edible portion. In the Coconut (fig. 193) both epicarp and mesocarp are dry and fibrous, whilst in the Almond and Walnut they are leathery.

The **berry**, as seen in the Gooseberry (fig. 194), Grape, Kei-apple, or Tomato, has the endocarp soft and succulent as well as the mesocarp, whilst the epicarp forms a skin. In the Gourd and Cucumber we have a fruit much resembling the true berry, but the outer layers are firmer and harder; such a variety of berry is known as a **pepo**. The fruit of the Orange is a multilocular berry.

In the **achene** (figs. 195, 206) all three layers of the fruit are dry; whilst if they are lignified, as in the Hazel Nut and Acorn (fig. 196), the term **nut** is employed.

Sometimes we have several fruits produced from the ripening of the apocarpous pistil of a single flower.

Thus in the Blackberry (fig. 197) we have several drupes. In the Buttercup and Strawberry we have a number of achenes (in the latter case, as we have seen, the edible portion is the enlarged thalamus) (fig. 198).

THE SEED.

We have already, in Chapter II., described the seed in a general manner; there are, however, a few details which it is necessary to note at this point.

In albuminous seeds, if the embryo is in the centre surrounded by the endosperm, as in the Pansy (fig. 199), the former is said to be **central**, and the latter **peripheric**.

The case is just reversed in the *Mirabilis Jalapa* (fig. 200),

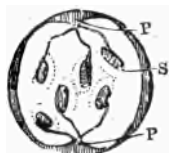


FIG. 194. — Transverse section through a Gooseberry; the firmer outer layer of the pericarp encloses the succulent flesh; the seeds lie embedded in the latter, and are attached by long funiculi to two opposite parietal placentæ.



FIG. 195.—Achene.

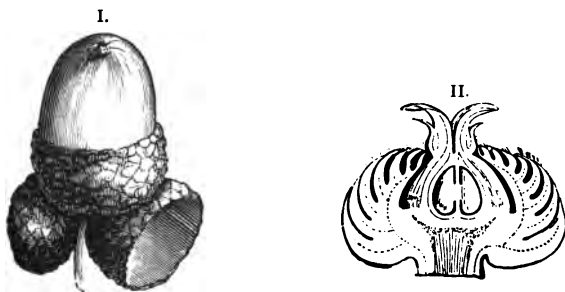


FIG. 196.—I. Acorn of *Quercus sessiliflora*, with two empty cupules. II. Longitudinal section through the fertilized pistillate flower, with the cupule in an early state.

where the peripheric embryo is bent round the central endosperm.

At other times the embryo and albumen are placed more side by side, when they are said to be **lateral** (fig. 201).

In some plants a peculiar appendage is developed from the

I.



II.



FIG. 197.—Fruit of Bramble (*Rubus*). I. Natural size. II. A single drupelet.



FIG. 198.—Pseudocarp of the Strawberry.

hilum of the ovule after fertilization, and, growing up round the seed, forms either a complete coat as in *Kiggelaria* and *Celastrus pyracantha*, a perforated coat as in the “mace” of



FIG. 199.—Peripheral endosperm surrounding the central embryo in the Pansy.



FIG. 200.—Peripheral embryo surrounding the central endosperm in *Mirabilis Jalapa*.



FIG. 201.—Lateral embryo of *Menispermum canadense*.

the Nutmeg, a solid cup as in *Schotia* (fig. 229), a fluffy cup as in *Strelitzia*, or hairs as in the case of the Willow. This is known as the **arillus**, and, except in the last case, serves as food to birds, which, in eating it, scatter the seeds.

CHAPTER XII.

DISTRIBUTION OF SEEDS.

PLANTS cannot move about like animals, hence their offspring would be crowded together with the parents, if they did not possess some means of spreading their seeds over a wider area. The principal agents assisting in this process are the wind, the animals, moving water, and some elastic contrivances in the ripening seed-vessels.

The wind.—The principal adaptations for distribution by wind are—

(a) Smallness and lightness of seeds, *e.g.* Heaths and Orchids. Seventeen hundred seeds of *Erica baccans* weigh only one grain.

(b) Wings, *e.g.* Gladiolus, Karrie tree (*Rhus viminalis*), Cluster Pine.

(c) Tails, *e.g.* Anemone, Clematis, Protea.

(d) Hairs, *e.g.* Composites, Hibiscus.

The animals assist in two ways—

(a) By transporting seeds and fruits which attach themselves to their skin or limbs by means of hooks or spines, *e.g.* Burr-weed (*Xanthium*), Grapple plant (*Uncaria*), Steek-grass (*Aristida* and *Andropogon*), and Klis-grass (*Panicum verticillastre*), Tribulus, Emex.

(b) By eating the juicy fruits and dropping the hard stony seeds, which are not injured by the digestive fluids. Examples are all plants with berries, drupes, etc.

Rivers transport the seeds of water-plants, which are mostly adapted to floating on water, *e.g.* Water-lily (*Nymphaea stellata*), *Aponogeton*.

Mechanical contrivances for throwing the seeds to some

distance are common in the orders Leguminosæ, Euphorbiaceæ, Geraniaceæ, and Acanthaceæ.

Some plants multiply and spread, not only by seeds, but also by vegetative means, *i.e.* by parts of their stems, *e.g.* runners, suckers, rhizomes, bulbs, etc.; or like the Prickly Pear and *Kleinia*, by any portion of a stem which touches the ground.

CHAPTER XIII.

THE MOVEMENT OF WATER IN THE PLANT TISSUES.

IN the tissues of a living plant there is a continual movement of water, the amount of movement being governed by various circumstances. This movement may be readily described under three heads.

1. **Slow Movement.**—Wherever cells are growing water is needed to aid their growth. Again, during the process of assimilation, water is the chief source of the hydrogen which is required for the formation of the organic materials. Also water is needed in the reservoirs where the assimilated food is stored up in order to re dissolve that food and convey it to the growing parts. All of these necessities cause a flow of water towards these parts. This flow, like the growth and assimilation, is slow. It is caused by osmosis, the growing cell absorbing water from the next, and so on till the source of water is reached. It takes place in the parenchyma and meristem of the stem. It is greatest during the spring and early summer—the time of most rapid growth.

2. **Rapid Movement.**—In plants which grow entirely under water the slow movement is the only one which exists. In all ordinary plants there is, however, another kind of movement going on due to the transpiration which we have seen takes place in the leaves. As water thus escapes, a fresh supply has to be obtained, and this passes up entirely through the xylem of the bundles, and not in the bark. If the supply is not sufficient to replace the loss, the leaves droop and wither. This is the reason why a branch cut from a tree so soon withers, as there is no water to compensate for evaporation.

If such a branch is placed in water, it cannot, as a rule, obtain a sufficiency of the needed liquid, owing to the fact that cutting the stem in the air acts upon the cut surface in such a way as to diminish its absorbing power. If, however, the stem is cut under water, absorption takes place as usual. That the current does take place through the wood can be shown—(1) If a ring of bark is cut off the stem of a growing plant, as long as the wood is uninjured the leaves will not droop; and (2) if the plant is watered with some coloured solution, it is found to rise in the wood, staining it. The amount of the flow of water in the wood depends upon the amount of transpiration. It is

greatest in the summer, when the transpiration is most rapid, and then the wood cells and vessels are partly or entirely filled with air. Hence the water must pass, not through the cell cavities, but in the cell walls.

Trees can be much more readily transplanted in the late autumn and winter than in the summer, because at the former times they are not so full of sap as when the leaves are fully expanded, and when they are transplanted at first the roots do not take up much water.

3. Root-pressure.—There is a third movement, which is due to root-pressure, and which depends neither upon growth nor evaporation. If the stem



FIG. 202.—Apparatus for measuring root-pressure.

of a plant is cut, and the surface is protected from evaporation, water is found to ooze out. This is caused by the pressure of the root. The amount can be measured by means of a manometer (fig. 202). Sometimes this root-pressure causes an

exudation of water in various parts of plants. Examples are to be seen in many Grasses, Aroids, *Alchemilla* and *Tropæolum*, where the water escapes in drops along the margins and at the tips of the leaves.

It is especially in spring that this root-pressure is noticeable. In summer, when active transpiration is going on, it is reduced to a minimum.

CHAPTER XIV.

WATER-STORAGE AND PROTECTION AGAINST THE EFFECTS OF DROUGHT.

IN a climate with such long dry seasons as occur in the greater part of South Africa, only such plants are able to exist as possess special means of protection against the effects of drought, besides the automatic action of the stomata common to all plants. As the loss of water in plants is almost entirely due to the transpiration of the leaves, it is in these organs particularly that we find the adaptations and modifications necessitated by a dry climate.

Some plants produce leaves only during or immediately after the rainy season, *e.g.* many Liliaceæ and Amaryllidææ; some have no leaves at all, the functions of the leaves being performed by green stems, *e.g.* Euphorbia, Mapelia, Cactus. In some the leaves become leathery and coated with a thick epidermis, *e.g.* Protea, Welwitschia; in others the leaves are thickly covered with hairs, which act like a layer of felt over the leaf, *e.g.* Everlastings, Silver tree; or wax and resin, like the leaves of *Rhus* and of the Blue-gum. In others, again, the stomata, through which, as stated before, the water-vapour escapes, are sunk into the epidermis, *e.g.* Aloe, Protea, Agave (fig. 100); or placed in so-called pits, *e.g.* Oleander; or in grooves, *e.g.* the stems of the Naras plant and the leaves of *Bobartia spathacea*, and many grasses (*Andropogon*, etc.).

In some plants the sap contains slime or gum, which prevents too rapid evaporation, and others store the water in a special tissue of the roots, *e.g.* *Anthericum*; or stems, *e.g.* *Stapelia*; or leaves, *e.g.* Aloe, Mesembryanthemum. The natives of the central and northern districts know very well

how to find such underground reservoirs of the precious liquid, e.g. the "Komaroo" (*Fockea*) and "Barroe" (*Cyphia*).

Often several of these contrivances, and some others not mentioned here, are combined, and enable plants to exist on the bare rocks of the desert, such as the coast-belt of Great Namaqualand, or in the Karroo, during droughts lasting many months or even years.

Another excellent illustration of the efficiency of these protective arrangements is supplied by the so-called "Kanniet dood" plants, several species of Aloe, especially *A. variegata*. Suspended in the air, they economize the water and food-materials originally contained in their leaves and stem so well, that they are able, not only to live a year or more, but also to produce flowers.

CHAPTER XV.

INFLUENCE OF HEAT AND LIGHT UPON GROWTH.

THE various vital phenomena can only be carried on within a certain range of temperature. There is a minimum below which and a maximum above which the activity ceases. The maximum and minimum vary with different plants and for the different processes of the same plant. Roughly speaking, however, from 0° C. to 50° C. may be looked upon as the range. Between the maximum and minimum there is always a temperature, the optimum, at which the vital function is most active.

Thus, taking the germination of Maize, 9.5° C. is the lowest temperature at which it is possible; as the temperature is increased, the Maize germinates more readily until the optimum is reached at 33.7° C. Beyond this the germination is less and less active until the maximum is reached at 46.2° C.

Comparing Wheat with this, we find that the minimum of germination is 5° C., the optimum 28.7° C., and the maximum 37.7° C.

The injurious action of high and low temperatures upon plants depends to a great extent upon the amount of water present. Dry peas do not lose their power of germination even if exposed to a temperature of 70° C. for an hour, whilst if wet a temperature of 54° C. will kill them. In the case of low temperatures, the injury is due to the water being separated from the protoplasm. It never freezes within the cell, but is separated and forms crystals of ice outside the cell wall. These crystals often considerably injure the tissues. If afterwards the thawing is gradual the tissues may recover, but if it is too rapid the water cannot be reabsorbed, and either rotting ensues, or the water evaporates and the plant dries up.

A curious effect of cold upon some plants is to change the colour of the chlorophyll. Thus the leaves of Pine, Juniper, and other plants, turn red or reddish brown under the influence of cold.

Light also plays an important part in the life and growth of plants. We may divide the effects of light under two heads.

1. **Chemical Action of Light.**—This is seen in the formation of chlorophyll, and in the decomposition of the carbon dioxide of the atmosphere, the assimilation of carbon, and the production of starch and other organic compounds. These changes can only take place in the light. A plant grown in perfect darkness will, as we have seen, be etiolated, and no starch will be formed. A very slight amount of light—the diffused light at the back of a room—will be sufficient to produce the green colour; but for the production of starch much brighter light is necessary. The conversion of one kind of organic material into another (such, for instance, as the conversion of starch into sugar during the germination of many seeds) can go on without the aid of light. A plant that contains a large reservoir of food materials will grow, nay, even produce flowers and fruit, in the dark; losing, however, instead of increasing in weight. The growth of tubers and bulbs in the dark and the germination of seeds are cases in point.

2. **The Mechanical Action of Light.**—Upon the development of the internodes of growing shoots light exerts a retarding influence. If a plant, such as a Broad Bean, is grown in darkness, it is found that not only does it present an etiolated appearance, but that the internodes are much longer than those of a corresponding plant grown in the light.

Again, if a plant is grown in a window, so that the sunlight falls upon only one side of it, very soon the stem will be found to bend over to the window. Such a bending is known as **heliotropism**. It is produced by the retarding influence of the light upon that side of the plant which is turned towards it. In some few cases the bending is in exactly the opposite direction. When the bending is towards the light it is called positive, and when away from it negative heliotropism.

CHAPTER XVI.

IRRITABILITY OF PLANTS.

NOT only is there a movement of plants or parts of plants during growth, but also certain fully formed organs of plants are motile, especially under the influence of an external stimulant. One of the best known examples is the Sensitive Plant (*Mimosa pudica*) (fig. 203). The leaves of this remarkable

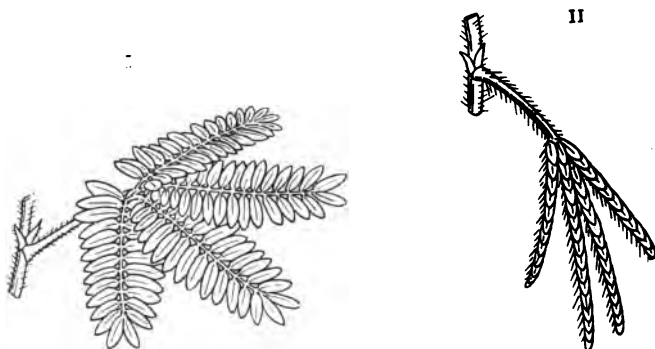


FIG. 203.—Leaf of *Mimosa pudica* ($\frac{1}{2}$ nat. size). I. At daytime when not irritated. II. At night or after vibration of branch. (After Duchartre.)

plant are bipinnate, and are articulated to the stem. The four pinnæ and the separate leaflets are also articulated. Spontaneously at evening, or under the influence of any irritant, the leaflets fold upwards, whilst the leaf-stalk as a whole bends downwards. The movement is due to the presence at the base of the stalk and of each leaflet of a mass of succulent parenchyma—the pulvinus. The cells are saturated with water, rendering them turgid. On irritation some of the water escapes into the intercellular spaces, and the elastic cell walls contract,

producing the movement. When the irritation is removed, the sap flows again into the tissue, causing the return of the leaf to its normal position.

The movement only takes place between the temperatures of 15°C. and 40°C. Oxygen appears to be necessary, as under the exhausted receiver of an air-pump, or in an atmosphere of hydrogen, nitrogen, or carbonic acid, the leaves of *Mimosa* cease to move. Anæsthetics, as chloroform, also cause a cessation of the movements.

I.



II.



Fig. 204.—I. *Oxalis cernua*, Thumb, at day-time. Flowers and leaflets drooping.
II. At night, flowers closed.

The leaves and leaf-hairs of Venus's Fly-trap (fig. 120) and Sundew are irritable. When a fly alights upon the surface of the leaf, it causes a bending over of the sides of the leaf to enclose it.

The stamens of many flowers are irritable. The Prickly

Pear and other species of *Cactus* are good examples. When an insect enters the centre of the flower, the neighbouring stamens bend over the intruder. In the flowers of *Protea*, the stigma is enclosed by the cohering perianth-lobes, and the growing style consequently must bend outwards through a slit in the perianth-tube. When a bird touches such a ripe floret, the tension of the style causes the perianth to split completely, the stigma, which is not yet ripe at this stage, throwing the pollen to some distance. In the flowers of *Loranthus*, birds render a similar service.

The leaflets of the sorrels fold down (fig. 204); those of the Clover, the Acacias, *Bauhinia*, *Cassia*, and many other plants, fold up.

The umbels of the carrot bend down in the evening, and raise themselves again in the morning, while many other flowers occupy similar sleeping and waking positions.

Changes of temperature and variation in the amount of light produce these movements.

The opening and closing of flowers at certain hours of the day is a phenomenon due to similar causes, some opening in bright sunshine only, e.g. *Mesembryanthemum*, *Oxalis*, many Composites; others at night only, e.g. *Hesperantha*, *Nycterinia*, *Oenothera* (Evening Primrose). The regularity of these movements induced Linnæus to arrange a "Floral clock."

Other movements are those executed by the growing points of twining plants. If a branch of such a plant, e.g. a Bean or *Convolvulus*, does not touch a support, it moves round through the air, describing a large spiral until it reaches a support. The same searching movement is made by the tendril of a Passion Flower or Grenadilla, which describes a circle of three to four inches in diameter within four to six hours.

CHAPTER XVII.

CLASSIFICATION.

UNDER the head of Classification we include the grouping of plants into classes according to their affinities. There are two great systems of classification, the *Artificial*, or (as it is often called) the Linnæan, and the *Natural*. In the former case the plants are arranged simply according to the number, position, and relation of their stamens and carpels ; in the second case the general structure and arrangement of the plant as a whole is taken into account. The result is that although the Artificial system is a most useful one for the purpose of tracing out a flower whose name we may wish to discover, yet, since it depends solely on the arrangement of one set of organs, it often separates plants which are evidently closely allied, and on the other hand unites those which possess no common properties beyond the structure of their flowers. For these reasons, for the purposes of classification, the Natural system is now always employed.

The sub-kingdom of Flowering Plants is divided into two classes, the **Dicotyledons** and **Monocotyledons**, most of the distinctive characteristics of which we have already noted, and hence it will only now be necessary to tabulate them as follows :—

DICOTYLEDONS.

Embryo with two cotyledons.
Primary root-growth exorhizal.
Growth of wood with open bundles, exogenous.
Leaves net-veined.
Parts of the flower arranged (as a rule) in fours or fives.

MONOCOTYLEDONS.

Embryo with one cotyledon.
Primary root-growth endorhizal.
Growth of wood with closed bundles, endogenous.
Leaves parallel-veined.
Parts of the flower arranged in threes.

Each of these classes is divided into sub-classes, of which there are six in the Dicotyledons and two in the Monocotyledons.

One of these sub-classes of the Dicotyledons is formed by the Gymnosperms, although they are provided with more than two cotyledons. Types for the other five sub-classes, which together form the Angiosperms, are the Buttercup (fig. 205), Orange (fig. 148), Rose (fig. 231), Heath (fig. 253), and Oak (fig. 264). If we compare their flowers we shall easily be able to understand the grouping.

In the first four specimens the flowers are **complete**; in the Oak **incomplete**, the calyx and the corolla being absent. The Oak stands, then, as a representative of the sub-class **Incompletæ**.

In the first three specimens the flowers are **polypetalous**; in the Heath the corolla is **gamopetalous**. The latter, therefore, is an example of the sub-class **Corollifloræ** or **Gamopetalæ**.

In the Buttercup the petals and stamens are **hypogynous**, which characterizes the sub-class **Thalamifloræ**; in the Orange-blossom they are inserted below a circular disc, upon which the ovary stands, hence the name of **Discifloræ** for such plants; whilst in the Rose they are **perigynous** (in some members of the group they are **epigynous**), and the sub-class is known as the **Calycifloræ**.

We may tabulate these results thus:

Dicotyledons	Angiosperms	Perianth double	Corolla polypetalous	Petals and stamens hypogynous	THALAMIFLORÆ.
				Petals and stamens inserted below conspicuous disc	DISCIFLORÆ.
		Perianth simple or absent	Corolla gamopetalous	Petals and stamens perigynous or epigynous	CALYCIFLORÆ.
					GAMOPETALÆ.
	Gymnosperms	Perianth simple or absent	Corolla gamopetalous		INCOMPLETÆ.
					GYMNOSPERMÆ.

The Monocotyledons are divided into two sub-classes: the **Petaloidæ**, which, like the Lily or Gladiolus, possess an evident perianth; and the **Glumacæ**, which, like the Grasses, have their flowers provided with those peculiar bracts known as glumes.

Each of these sub-classes is divided into several natural orders; in this work we shall deal with a few of the principal.

DICOTYLEDONS.

GROUP 1.—*Polypetalæ*.

Sub-class I.—THALAMIFLORÆ.

Pistil apocarpous. Petals few; stamens many. RANUNCULACEÆ.

Pistil syncarpous.

a. Stamens 4-10, free.

Corolla cruciform; stamens tetradynamous

CRUCIFERÆ.

Leaves opposite. Stem swollen at nodes.

Petals 5; free central placenta CARYOPHYLLÆÆ.

β. Stamens numerous, monadelphous MALVACEÆ.

Sub-class II.—DISCIFLORÆ.

Glands of torus (disc) usually prolonged through the centre of the ovary. Leaves without glands

GERANIACEÆ.

Disc between the stamens and ovary, annular or expanded. Leaves with pellucid glands

RUTACEÆ.

Sub-class III.—CALYCIFLORÆ.

Pistil apocarpous.

a. Pistil monocarpellary. Flowers papilionaceous except in Cæsalpinæ and Mimoseæ

LEGUMINOSÆ.

β. Pistil (in South African genera) of 2 or more carpels.

Stamens numerous ROSACEÆ.

Stamens 4-10; ovary of 4-7 carpels CRASSULACEÆ.

Pistil syncarpous. Flowers in umbels. Fruit a cremocarp

UMBELLIFERÆ.

GROUP 2.—*Gamopetalæ*.

Sub-class IV.—GAMOPETALÆ.

I. Ovary Inferior.

a. Stamens inserted in the corolla tube; ovary 1-celled with 1 ovule. Fruit an achene.

Seeds exalbuminous COMPOSITÆ.

Ovary 2 or more celled. Seeds with copious albumen

RUBIACEÆ.

β. Stamens epigynous, free from the corolla; ovary 2-10-celled. Fruit a capsule

CAMPANULACEÆ.

II. Ovary superior.

a. Flowers regular.

Parts of the flower arranged in fours. Stamens

hypogynous ERICACEÆ.

b. Flowers irregular. Corolla bilabiate.

Ovary 2-celled, many ovuled. Fruit a

capsule SCROPHULARIACEÆ.

Ovary deeply 4-lobed or 4-celled, with 1

ovule in each cell. Fruit formed by 4
separable nuts LABIATÆ.GROUP 3.—*Incompleteæ*.

Sub-class V.—INCOMPLETEÆ.

I. Perianth present.

Flowers regular. Perianth tubular, its lobes

imbricate in bud. Shrubs THYMELEÆ.

Flowers more or less irregular. Perianth 4-cleft

or 4-parted, its lobes valvate in bud. Trees
or shrubs PROTEACEÆ.

II. Perianth absent.

Flowers unisexual. The males in the axils of

the scales of catkins AMENTACEÆ.

Sub-class VI.—GYMNOSPERMS.

Flowers unisexual. Females of naked ovules

in spikes or cones CONIFERÆ.

MONOCOTYLEDONS.

GROUP 1.—*Fetaloidæ*.

I. Ovary inferior.

Stamen 1, gynandrous ORCHIDÆÆ.

Stamens 3, free from pistil IRIDÆÆ.

Stamens 6 AMARYLLIDÆÆ.

II. Ovary superior.

Flowers hermaphrodite. Perianth showy; sta-

mens 6; anthers introrse LILIACEÆ.

Dioecious. Perianth of 6, rarely 4, glumes in

2 rows; stamens 3 RESTIACEÆ.

GROUP 2.—*Glumaceæ*.

Stem solid. Sheath of leaves not split. No ligule

present CYPERACEÆ.

Stem hollow. Leaf-sheath split. Ligule present . GRAMINEÆ.

Each of these orders contains numerous plants, which are arranged in *genera* and *species*. A genus is an assemblage of plants which resemble one another more closely in general

structure and appearance than they do other species of plants. Thus, if we examine the Karroothorn, the Camelthorn, and the Hookthorn, we find that although they differ in many minor points of detail, yet there is a great resemblance between them, which causes them all three to be grouped under the genus *Acacia*. By a species we mean an assemblage of individuals which, whilst possessing the characteristics of the genus, possess in addition distinctive characters which separate them from the allied plants of the same genus. Thus the points in which the three *Acacias* agree would be their generic characters; whilst the points in which they differ are their specific characters. When the seed of a plant is grown, it always reproduces the same species as the parent. In giving the name of a plant, we place the generic name first, followed by the specific name. Thus the Karroothorn is *Acacia horrida*, the Camelthorn is *Acacia Giraffe*, and the Hookthorn is *Acacia detinens*.

Sometimes the pollen of one species will fertilize the ovule of a closely allied species, and a plant is thus obtained which combines the properties of both. Such a plant is said to be a *hybrid*.

RANUNCULACEÆ.

Flowers of indigenous species, regular. **Sepals** usually 5 (*Clematis* 4, *Anemone* many). **Petals** usually 5 (absent in *Clematis* and *Anemome*). **Stamens** numerous, hypogynous,

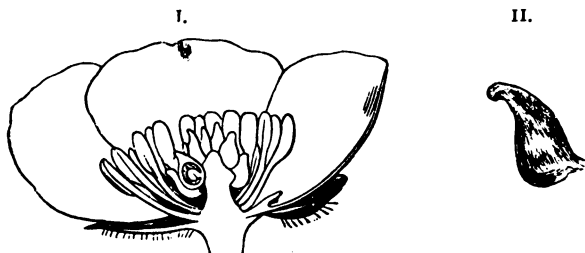


FIG. 205.—I. Longitudinal section through the flower of *Ranunculus acris*, showing the hypogynous calyx, corolla, and stamens. II. Achene.

inserted on a more or less developed thalamus. **Carpels** several or many, distinct.

Herbs except *Clematis*.

Ranunculus (Buttercup). Flowers yellow. Petals with nectaries near their base. Achenes beaked (fig. 205, II.). Several European species occur as garden weeds; a few are indigenous.

Anemone (fig. 207). Calyx showy; sepals numerous. Achenes tailed. *A. capensis* and *A. Caffra*.



FIG. 205.—Pheasant's-eye (*Adonis*). Longitudinal section through achene.



FIG. 207.—Flower of *Anemone capensis*.

Clematis. Sepals showy, 4. Achenes provided with feathery tails. Common climber in woods.

(NOTE.—Although the flowers of this and other plants of the order are incomplete, yet we place them in this thalamifloral order because their general affinities resemble those of the other plants of the group. Similar exceptions occur in most other orders.)

CRUCIFERÆ.

Flowers bisexual. Sepals 4. Petals 4, clawed, spreading in the form of a cross. Stamens 6; tetradynamous. Ovary 2-celled, with parietal placentæ. Fruit a siliqua or silicula. Seeds exalbuminous.

Herbs or shrublets with alternate exstipulate leaves. Flowers racemose.

Heliophila, with over sixty species, is the most important South African genus of this order. Flowers mostly blue.

Cultivated plants are—

Brassica. A large and important genus. *B. oleracea* comprises all the varieties of Cabbage, Cauliflower, and Broccoli;

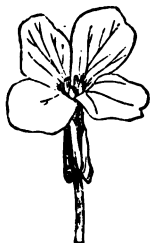


FIG. 208. — Cruciform flower of *Lunaria*, with unguiculate petals.

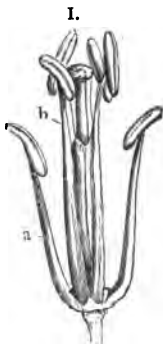


FIG. 209. — I. Tetradynamous stamens and pistil of *Brassica nigra*: a, shorter, b, longer stamens.

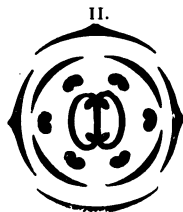


FIG. 210. — Wallflower (*Cheiranthus Cheiri*). Siliqua.



FIG. 211. — Silicula of *Cochlearia*, open and showing the seeds attached to the replum.



F.G. 212. — Lomentum of *Raphanus*.

* These floral diagrams do not represent horizontal sections through the flowers, but vertical projections of the upright flowers upon a horizontal plane. The mode of representing sepals, petals, etc., is purely conventional.

B. rapa, Turnip; *B. campestris*, Swedish Turnip; *B. napus*, Rape; *B. sinapis*, Mustard. *Raphanus*, Radish. *Nasturtium*,* Watercress. *Cheiranthus*, Wallflower. *Matthiola*, Stock. *Cap-sella*, Shepherd's-purse, a common garden weed.

CARYOPHYLLÆ.

Flowers regular. Calyx 4 to 5, cleft or parted, **persistent**. Petals **free**, 5, rarely 4. Stamens 5 or 10, rarely less, **inserted with the petals on a hypogynous ring**. Ovary free, 1 celled;

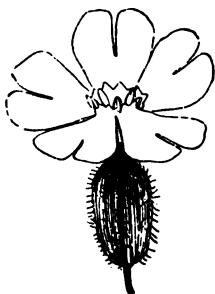


FIG. 213.—Caryophyllaceous corolla of *Lychnis vespertina*, with corona.



FIG. 214.—Longitudinal section through the caryophyllaceous corolla of *Dianthus*.

ovules numerous (rarely few), attached centrally; styles 2, 3, or 5. Fruit a capsule, mostly opening with teeth.



FIG. 215.—Capsule of *Silene gallica*, L.

Herbs or half-shrubs. Branches mostly swollen at the nodes. Leaves opposite, quite entire. Inflorescence mostly a dichotomous cyme (fig. 127).

Dianthus, Pink (fig. 214). Calyx tubular, with 2 or more close-lying bracts at its base. Petals 5, with long claws. Stamens 10. Styles 2, filiform. Several South African species. The garden Pink and Carnation belong to this genus.

Silene. Calyx tubular, ebracteate. Petals 5. clawed. Stamens 10. Styles 3. Capsule opening by 6 teeth.

* This name is often erroneously applied to the Indian Cress (*Tropæolum*), especially by gardeners.

Several species of Campion, also the so-called "Gunpowder weed" (*S. gallica*).

Stellaria. Sepals separate. Petals 5, not clawed, bifid. Styles 3. Chickweed (*St. media*).

MALVACEÆ.

Flowers regular. Calyx 5 fid, mostly with epicalyx; petals 5, twisted in bud, attached to the base of the staminal column. Stamens many, monadelphous (fig. 146).

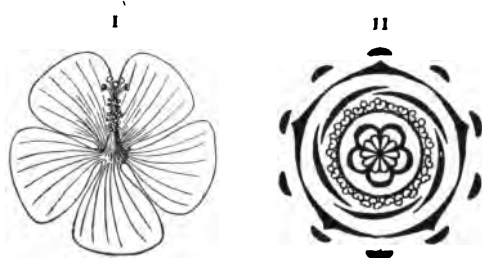


FIG. 216.—*Hibiscus æthiopicus*, L. I. The expanded flower after the removal of the calyx. II. Diagram of flower with epicalyx.

Malva, Mallow (fig. 218). Carpels separable at maturity.
Hibiscus (figs. 216, 217) Staminal column 5-toothed at



FIG. 217.—Capsule of *Hibiscus urens*.



FIG. 218.—Multipartite schizocarp of *Malva*.

the apex. Capsule 5-celled, dehiscent. Seeds glabrous or woolly, like those of the Cotton-plant (*Gossypium*).

GERANIACEÆ.

Sepals 5. Petals 5, free. Stamens 5 or 10 or 15, sometimes less by abortion; filaments mostly connate at base. Ovary mostly 5-lobed and 5-celled; styles 5.

This order principally consists of two well-marked suborders.

I. Oxalidæ. Flowers regular. Petals convolute, their claws conniving into a funnel-shaped tube. Stamens 10,

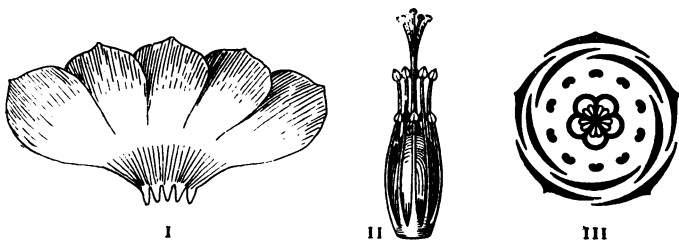


FIG. 219.—*Oxalis cernua*. I. Corolla. II. Stamens and pistil. III. Diagram of flower.

5 alternate shorter, trimorphic (fig. 178). Styles separate; stigmas capitate. Fruit a pulpy capsule.

Oxalis (Sorrel) (fig. 204). Herbs mostly bulbous, with

I.

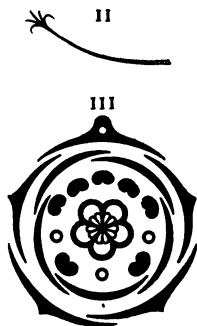


FIG. 220.—*Pelargonium cucullatum*. I. Section through flower, 2½ sepals and 2½ petals being removed; Sp, hollow spur of upper sepal. II. Style and stigmas of a flower in the second (female) stage. III. Diagram of flower.

compound leaves, tri- or pluri-foliolate. Over 100 Cape species.

II. Geraniæ. Sepals unequal; petals quite free. Stamens.

monadelphous or polyadelphous. Ovary beaked; stigmas linear. Fruit of 5 one-seeded carpels, tailed by the persistent styles (fig. 221).

Geranium. Flowers regular. Stamens 10, all perfect, the alternate ones longer. Five Cape species.

NOTE.—The so-called “Geraniums” of gardens mostly belong to the genus “Pelargonium.”

Monsonia. Stamens 15, connate at base, and cohering in 5 parcels for half their length. *M. speciosa* has large showy flowers (red with dark centre).

Sarcocaulon. Stamens 15, not cohering in parcels. Rigid shrubs, armed with spines formed from the persistent petioles. Bark strongly impregnated with wax, hence the name Candle-bush in the northern and central districts.

Pelargonium (fig. 220). Flowers irregular. Calyx 5-parted, the upper segment produced at base into a slender nectariferous tube, adnate to the pedicel. Petals 5, of which 2 are mostly larger. Filaments 10, unequal, monadelphous, 2-7 bearing anthers, the others barren.

There are over 160 South African species, many of which are cultivated and hybridized in Europe.

RUTACEÆ.

Flowers regular. Petals 5. Stamens 5, inserted at the base or on the margin of a disc, which is mostly annular. Carpels 5. Fruit mostly a 5-celled dehiscent capsule.

Trees or shrubs with gland-dotted, strongly scented leaves.

Calodendron capense (Cape Chestnut) is a noble tree of the eastern regions.

Diosma. Petals sessile, not bearded. No staminodes. Small shrubs with linear leaves and mostly white flowers.

Adenandra (fig. 223). Stamens 5; anthers tipped with a



FIG. 221.—Quinquepartite schizocarp of *Geranium Robertianum*. I. The immature pistil. II. The mature fruit.

stalked, spoon-shaped gland. Stamines 5, also tipped with a gland. Flowers large, mostly white.

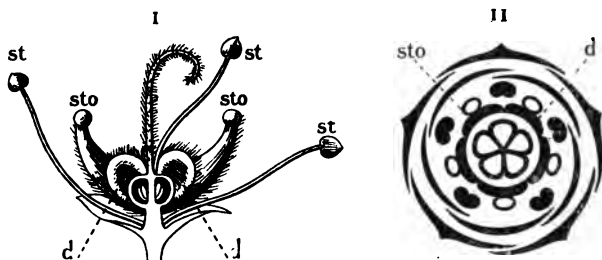


FIG. 222.—I. Section through flower of *Barosma crenulata* after the removal of the petals (magnified): *st*, fertile stamens; *sto*, barren stamens (staminodes); *d*, lobes of disc. II. Diagram of flower: *sto*, staminodes; *d*, disc.

Barosma (fig. 222). Petals much longer than the calyx; stamens 5. Staminodes petaloid, filiform; anthers ovoid. Disc cup-like. Flowers axillary.



FIG. 223.—Flower of *Adenandra uniflora*. Leaves with oil-glands.

B. crenulata, the "Buchu," occurs along mountain streams of the western region.

Agathosma. Petals with long claws. Flowers at the end of the branches, capitate or umbellate. Over 100 species.

The genus *Citrus* (Orange, Citron, Lemon, Pomelmoose, Shaddock) belongs to another sub-section of this order.

LEGUMINOSEÆ.

This order consists of three sub-orders, which differ in their floral characters, but agree with each other in their fruit, which is a legume.

I. *Papilionaceæ*. Corolla papilionaceous, æstivation imbricated, descending (fig. 224). Stamens 10, diadelphous, monadelphous, or free.

Podalyria. Stamens free. Shrubs with simple leaves.

P. calyptrata with large purplish-rosy flowers is common along streams.

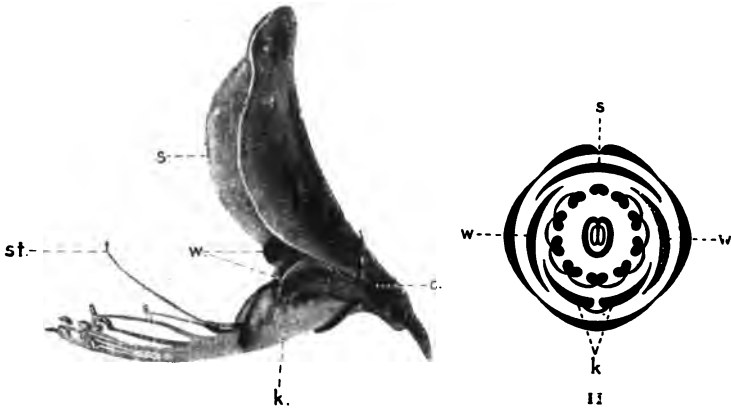


FIG. 224.—*Erythrina caffra*. I. Flower. II. Diagram: s, standard; w, wings; k, keel; c, calyx; st, style.

Crotalaria. Stamens monadelphous. Legume turgid (inflated). Half-shrubs with yellow flowers.



FIG. 225.—Abbreviated inflorescence of Clover.

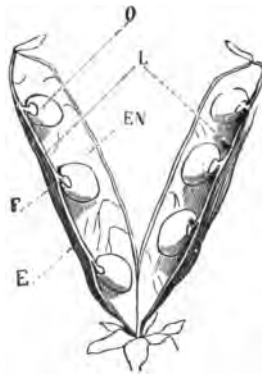


FIG. 226.—Legume of Pea split lengthwise: E outer, EN inner, layer of the pericarp; L, placenta; f, funiculus; o, seed.

Aspalathus. Nearly allied to *Crotalaria*, but the legumes

are not turgid. Shrubs or half-shrubs with heath-like sessile leaves. 150 species.

Psoralea. Stamens diadelphous. Ovary 1-ovuled. Legume concealed in the calyx tube.

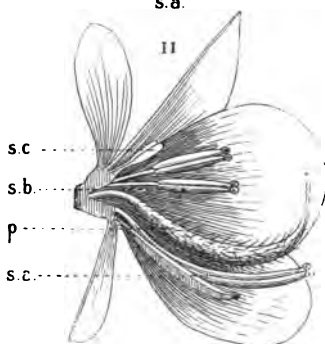
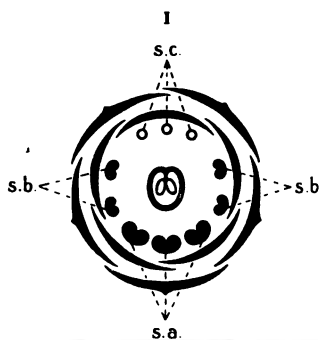


FIG. 228.—*Cassia arachoides*. I. Diagram of flower. II. Vertical section of flower: *sa*, large stamens; *sb*, small stamens; *sc*, staminodes.



FIG. 227.—Twisted legume of Lucerne (*Medicago sativa*).



FIG. 229.—*Schotia latifolia*. Legume opened showing the seeds with their large arillus.

Indigofera. Stamens diadelphous; anthers apiculate. 120 species.

Erythrina (fig. 224). Stamens diadelphous, exserted. Trees or shrubs with 3 foliolate leaves.

E. Caffra (Kafir tree) is a fine ornamental tree of the eastern regions.

Virgilia. Stamens free; leaves pinnate.

V. capensis (Keurhout) is a tree common along rivers throughout the country.

II. Cæsalpiniacæ. Corolla irregular (more or less); æstivation ascending (fig. 228). Stamens 10 or less, monadelphous or free.

Schotia. Stamens 10, more or less connate at base. Ovary stipitate. Trees with pinnate leaves. The seeds of *Sch. latifolia* (Boerboon) (fig. 229) are used as food (fig. 114).

Bauhinia. Stamens 10. Trees or shrubs with leaves formed of two partially cohering leaflets (Goat's Foot), chiefly in the Northern region, where the "Mopane" tree, mentioned by Livingstone, forms beautiful groves and little forests.

Cassia. Stamens 10, the 3 upper sterile; the fertile anthers opening by terminal pores (fig. 228). *C. arachoides* (Wild Senna), with branches appressed to the ground and racemes of yellow flowers, is common in the Central and Northern regions.

III. Mimosæ. Flowers minute, in dense heads or spikes. Corolla regular; petals valvate (fig. 230).

Acacia. Calyx tubular; petals 5, valvate; stamens many. Trees or shrubs with pinnate leaves and spines (stipular or axillary) or prickles, both being very sharp, either straight or recurved.

A. horrida (Karoothorn) is common throughout the country along watercourses. The older trees yield "gum arabic," especially in the dryer regions, e.g. Great Namaqualand. *A. Giraffæ* (Camel-thorn), highly valued as fuel on the

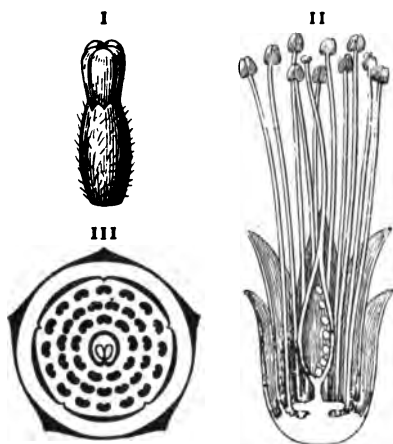


FIG. 230.—*Acacia horrida*. I. Flower-bud ($\times 3$). II. Section through flower ($\times 5$). III. Diagram of flower.

diamond-fields, was formerly common throughout the country north of the Orange River. It occurs in Colonial territory at present only where protected against the woodcutter, but in the Kalahari extensive groves of this beautiful tree may be still seen.

The more important cultivated plants are : Pea (*Pisum*), Bean (*Phaseolus*), a native of South America, Lentil (*Ervum*), Vetches (*Vicia*), Lucerne (*Medicago sativa*), Clover (*Trifolium*), Sweet Pea (*Lathyrus*), Indigo and Earth nuts (Monkey nuts) (*Arachis*), the two latter plants being grown in the subtropical parts (Natal, etc.).

ROSACEÆ.

This order contains only a few indigenous genera, e.g. *Rubus*, *Cliffortia*. It is very important, however, on account of the many cultivated plants belonging to it

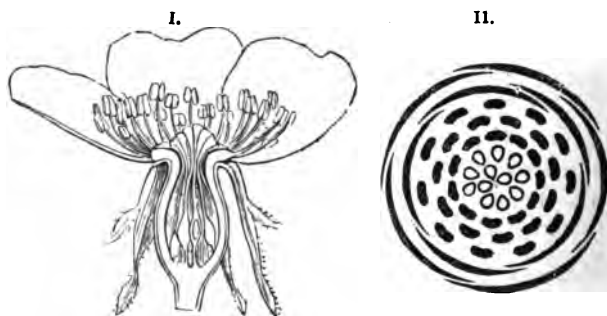


FIG. 231.—I. Longitudinal section through the rosaceous flower of the Rose; the pistil seated in the base of the urceolate calyx. II. Floral diagram of the Rose.

For a typical flower we may choose the peach. Calyx cup-shaped with 5 segments. Petals 5, perigynous. Stamens numerous, perigynous. Pistil apocarpous, inferior.

There are four sub-orders, which differ principally in their pistils and fruits.

1. **Drupacæ.** Pistil simple. Fruit a drupe (fig. 192).

Prunus. Plum, cherry.

Persica. Peach, apricot

Amygdalus. Almond.

2. Roseæ. Pistil of many carpels. Fruit, an etærio.

Rosa. The white Hedge-rose (from China) and the English briars have simple flowers; the many other garden roses have become double by cultivation.

Rubus. Bramble and Blackberry. Fruit an etærio of little drupes. Several indigenous species with black or golden fruits.

Fragaria. Strawberry. Fruit an etærio of achenes which are inserted on an enlarged and fleshy receptacle.

3. Pomeæ. Carpels 3 to 5. Fruit a pome (fig. 180).

Pyrus. Pear, Apple.

Cydonia. Quince, from Southern Europe.

Eriobotryon. Loquat, from Japan.

4. Sanguisorbeæ. This sub-order is well represented here by the large genus—



FIG. 232.—Longitudinal section through the flower of the Pear.



FIG. 233.—I. Branch of *Cliffortia ruscifolia*, L., with one staminate flower ($\frac{1}{2}$ natural size). II. Male flower. III. Section through female flower. II and III. $\times 2$.

Cliffortia (fig. 233). Dioecious. Calyx with 3 segments; corolla absent. Male flower with numerous much exserted stamens. Female flower, 2 carpels with feathery stigmas. Fruit of 2 achenes, enclosed in the persistent calyx tube. This genus, of about 45 species, is peculiar to South Africa. Shrubs or half-shrubs. Flowers axillary.

CRASSULACEÆ.

Flowers regular. Petals, mostly 5 (from 4 to 7), in-

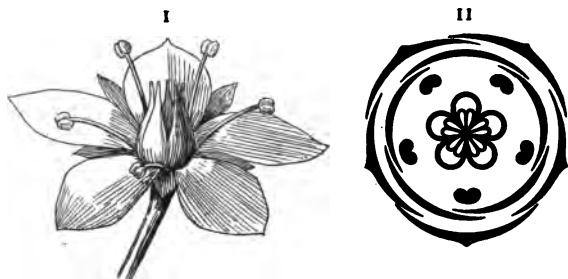


FIG. 234.—*Crassula centauroides*, Thumb. I. Flower ($\times 2$). II. Diagram of flower.



FIG. 235.—*Cotyledon orbiculata*, L. (†).

serted in the bottom of the calyx. Stamens inserted with the petals, as many or twice as many. Ovary of 4 to 7 (mostly 5). Carpels, which are apocarpous, but sometimes slightly cohere at their base; styles subulate, free. Fruit of several follicles.

Succulent plants with entire (rarely divided) leaves and cymose flowers.

Crassula (fig. 234). Petals free; stamens 5. Herbs with succulent leaves. About 100 species.

Rochea. Petals slightly cohering, hence corolla tubular. Stamens 5.

Cotyledon (fig. 235). Corolla gamopetalous, with a reflexed limb (5-parted). Stamens 10. Shrubby or half-shrubby.

UMBELLIFERÆ.

Inflorescence an umbel, simple or more often compound.

Flowers small. **Calyx** adhering to the ovary; limb 5-toothed or obsolete. **Petals** 5, inserted on the outside of a fleshy epigynous disc. **Stamens** 5, alternate with the petals. **Ovary** inferior, consisting of two carpels. **Fruit**, a schizocarp, splitting into 2 mericarps, which cohere by their inner faces, and are attached to a central slender axis (carpophore) (fig. 237). The mericarps are marked with five longitudinal ribs, and contain longitudinal oil-vessels in the pericarp. Albumen copious.

Mostly herbs, rarely shrubs (e.g. *Heteromorpha*).

(The characters which distinguish the genera are mostly taken from the fruit, and require very close inspection by the student.)

Sub-order ORTHOSPERMÆ.

Albumen flat or not grooved on its inner surface (fig. 236, v.).

Hydrocotyle. Umbels simple, commonly with three flowers, of which one only is fertile. Fruit laterally compressed. Herbs of very different aspect.

Peucedanum. Umbels compound. Petals emarginate. Fruit dorsally compressed, flat, with a dilated flattened margin.

Bubon (fig. 236). Umbels compound. Petals entire with an acute involute point. Fruit dorsally compressed, with a narrow margin.

B. Galbanum, Wild Celery, is a common half-shrub, with large greenish-yellow umbels.

Sub-order CAMPYLOSPERMÆ.

Albumen with a longitudinal furrow along its inner face (figs. 236, vi., 237).

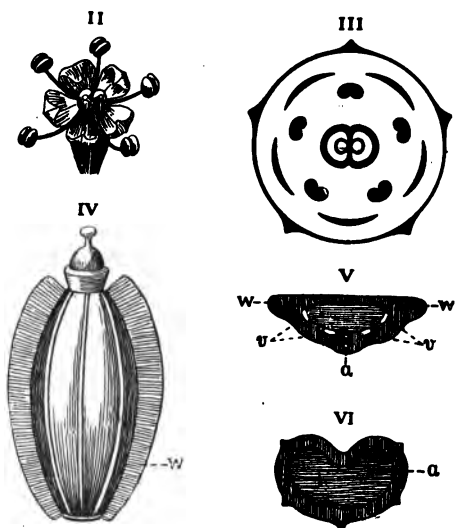


FIG. 236.—*Bubon Galbanum*. I. Flowering branch. II. Flower (magnified). III. Diagram of flower. IV. Mericarp (magnified). V. Transverse section through mericarp: *a*, albumen; *v*, vittæ (oil-channels); *w*, wings. VI. Mericarp of conium, transverse section.

Hermas gigantea has large woolly leaves (Tondel blaren).
Arctopus, e.g. *A. echinatus*, is a dioecious stemless plant,

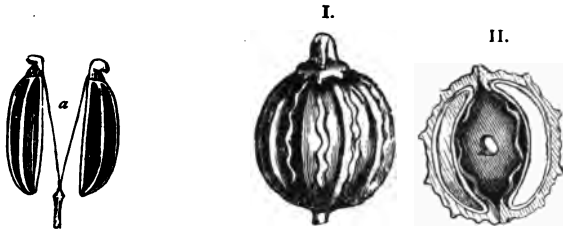


FIG. 237. — Fruit of the Fennel: *a*, carpophore.

FIG. 238. — I. Fruit of Coriander (*Coriandrum sativum*). II. Transverse section.

with a rosette of spiny leaves close pressed to the ground.
 Cultivated plants are the Carrot (*Daucus*), Parsnip

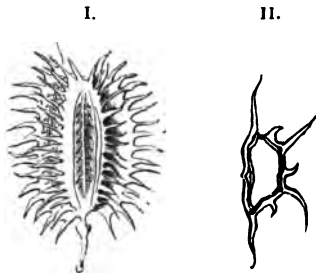


FIG. 239. — I. Fruit of Carrot (*Daucus Carota*). II. Transverse section: the four secondary ridges are conspicuous; of the primary ridges the two lateral ones are scarcely visible, the median (carina) and intermediate ones are spiny.

(*Pastinaca*), Celery (*Apium*), Parsley (*Petroselinum*), Caraway (*Carum*).

RUBIACEÆ.

Flowers regular, bisexual. Calyx tube adnate. Corolla gamopetalous, epigynous, mostly 5 (rarely 4 or 6) lobed. Stamens inserted on the corolla, as many as its lobes, and alternate with them. Ovary inferior, 2 or more celled. Fruits mostly dimerous. Seeds with copious albumen. Herbs, shrubs, or trees, with opposite entire leaves, and interpetiolar

stipules. Principally Eastern, a few species occurring in the Western parts.

Gardenia (fig. 240). Corolla salver or funnel shaped, often with a long tube ; limb 5 to 9 parted, twisted in bud. Anthers nearly sessile, in the throat of the tube, exserted. Fruit a hard-shelled berry.

Trees or shrubs with mostly white, showy, sweetly scented flowers, indigenous to the Eastern regions, but sometimes grown in the gardens of the West. Called "Katje piering."

Platonia. Shrubs, often armed, with edible drupes. One species (*P. ventosa*) common in the Western districts.

Hedyotis. Small herbs with whitish flowers, about 20 species, some of which are very common.

Anthospermum belongs to a peculiar section of this order. Flowers often dice-

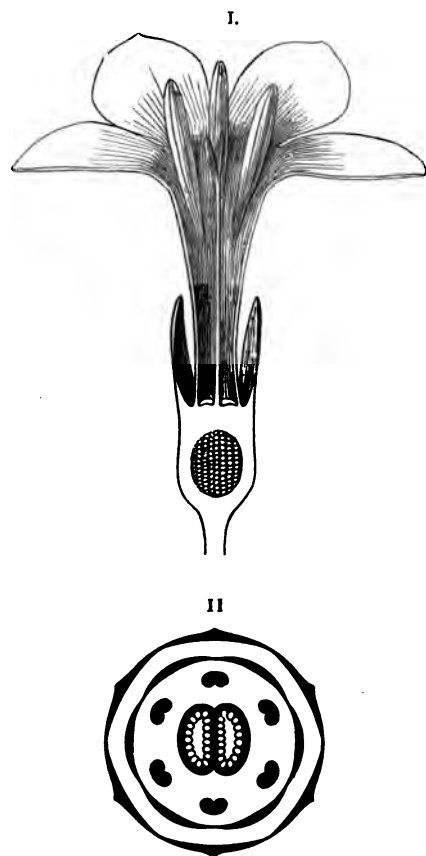


FIG. 240.—*Gardenia florida*. I. Section through flower. (After Baillon.) II. Diagram of flower.

cious. Corolla tubular, limb 4 to 5 parted, the lobes linear or lanceolate. Stigmas 2, very long and hairy. Fruit of two easily separable little nuts. Small, much branched, closely leafed shrubs or herbs (20 species). Leaves opposite or whorled ; flowers axillary, small.

Galium (fig. 241). Corolla 4-parted, rotate; styles 2, with capitate stigmas. Fruit 2-parted. Leaves 4 or more in a whorl (see fig. 118).

COMPOSITÆ.

Flowers arranged in **heads** (capitula) on a general receptacle, surrounded by an involucre. Head mostly many-flowered, rarely few, or even 1-flowered. **Calyx-tube adnate**; limb (called **pappus**) very much varied, either obsolete, coroniform, toothed, or scaly, or formed by bristles, which are smooth, scabrous, or feathery. **Corolla epigynous**, tubular, or strap-shaped. **Stamens** inserted in the tube of the corolla; **anthers** usually united by their edges into a tube surrounding the style. **Ovary** 1-ovuled; style filiform, 2 fid in the fertile flowers. The ray flowers are often without stamens or quite barren. **Fruit** an **achene** crowned by the pappus.

This vast order is represented in South Africa by about 1500 species, which form several tribes, for which the shape of the style-branches is characteristic.

A. TUBULIFLORÆ.

Disk flowers, tubular, regular, 5-toothed.

1. **Vernoniaceæ**. Style branches long, filiform, much exserted, equally hispid on the outer surface.

Corymbium. Heads 1-flowered; involucre cylindrical, consisting of 2 opposite scales. Heads arranged in corymbs. Corolla deeply 5-cleft. Nearly stemless plants with *parallel-nerved* leaves.

2. **Asteroidæ**. Style branches linear, flattish, mostly acute, minutely and equally downy on the outer surface (fig. 246).

Aster. Heads many-flowered, radiate. Rays female, mostly blue, never yellow. Pappus of many serrulate bristles.

Tarchonanthus. Heads diœcious. Achenes very woolly, without pappus. Leaves grey, aromatic.

T. camphoratus is a socially growing shrub, very common in the Central and Northern regions.



FIG. 241.—*Galium tomentosum*. Transverse section through the dimerous fruit: *a*, albumen; *e*, embryo.

3. *Senecioides*. Style branches linear, flattish, truncate, bristly at the apex only, or topped with a short bristly cone.

This tribe comprises the greater number of Cape composites.

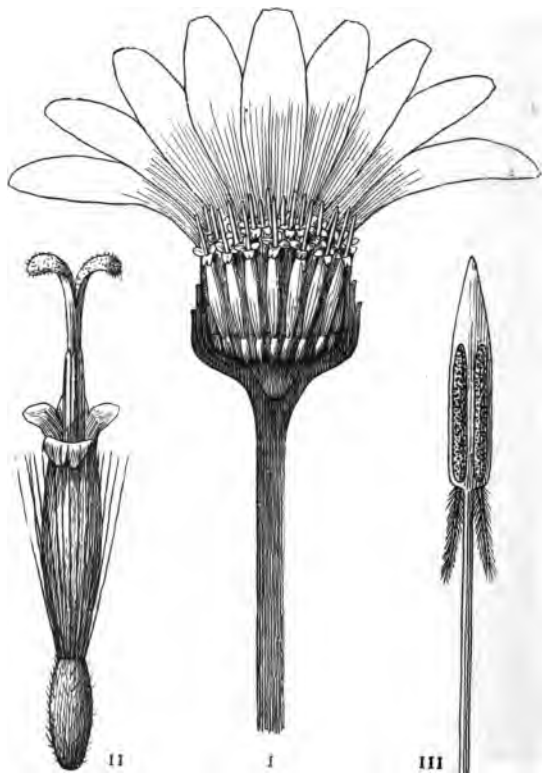


FIG. 242.—*Gerbera asplenifolia*. I. Section through capitulum. II. Disc-flower. III. Stamen.

Sphenogyne. Heads radiate; rays yellow on their upper and mostly coppery on their lower surface. Pappus of about 5 obovate milk-white scales (fig. 250). Over 40 species.

Pentzia. Heads discoid. Achenes angular. Pappus membranous, shortly tubular.

P. virgata forms the principal pasturage for sheep in the central districts. "Good Karroo-bush."

Helichrysum. Heads discoid; involucre dry and mem-
I.

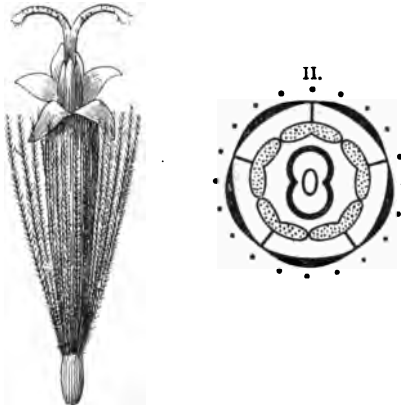


FIG. 243.—*Helipterum canescens*. I. Flower.
II. Diagram of disc-flower.

branous. Pappus of slender scabrous bristles. Over 140 species, of which *H. vestitum* is the "Everlasting" so largely exported.

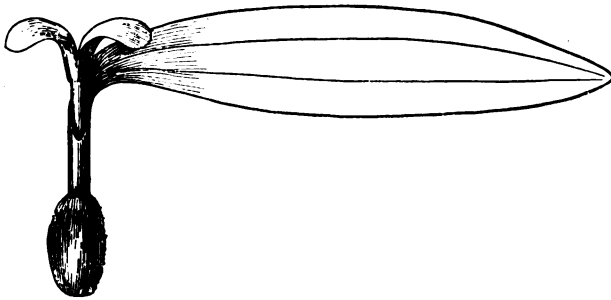


FIG. 244.—*Venidium hirsutum*. Ray-flower.

Elytropappus. Heads small, 2 to 8 flowered; pappus formed of several broad-based bristles.

E. rhinocerotis, the so-called "Rhenoster bush," is a common pest on large tracts of country.

Othonna. Heads radiate; ray flowers female. Involucral scales, 1 seriate, more or less concrete; anthers rounded at base. About 60 species.

Senecio (fig. 136). Heads either discoid or radiate; involucre, 1 seriate; involucral scales, mostly with withered dark tips; style branches of the disc flowers truncate; pappus multiseriate, pilose. About 200 South African species. Flowers yellow or purple.



FIG. 245.—Tubular corolla from the disc of the capitulum of *Centaurea Cyanus*.



FIG. 246.—*Mairea crenata*. Style.

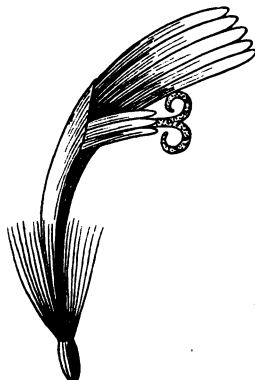


FIG. 247.—*Sonchus oleraceus*. Flower.

4. **Cynareæ.** Style suddenly thickened below the apex, and often hispid at the point of thickening (figs. 244, 242).

Arctotis. Heads radiate. Receptacle honeycombed, fimbriiferous. Achenes copiously silky, dorsally 3 to 5 winged. Pappus paleaceous.

Cryptostemma. Heads radiate. Achenes wingless, very thickly clothed with long silky hairs. Pappus small, paleaceous.

C. calendulaceum (flowers yellow with black centre) is a common weed in waste places throughout the Colony.

Gazania. Heads radiate; involucral scales in 2 or more rows, concrete below into an urceolate cup. Achenes wingless,

very villous. Herbaceous, perennial, mostly stemless plants. Heads sometimes very large and showy, mostly with yellow or orange rays and dark brown or black centre. Deserving of cultivation. *G. pinnata* is very widely spread.

Gerbera. Heads radiate ; ray flowers bilabiate (fig. 242). Anthers tailed. Pappus of numerous rough bristles.

B. LIGULIFLORÆ.

Flowers all strap-shaped and bisexual.

5. *Cichoriaceæ*. Style branches long, filiform (fig. 247).

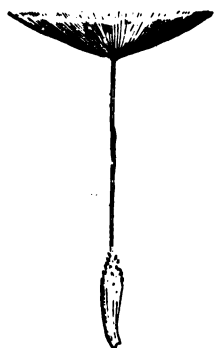


FIG. 248.—Pilose stipitate pappus of Dandelion.



FIG. 249.—Plumose sessile pappus of *Tragopogon*.

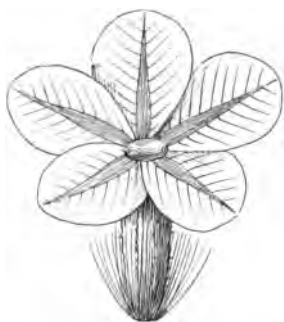


FIG. 250.—*Sphenogyne anthemoides*. Achene with scaly pappus.

Lactuca (Lettuce), *Cichorium* (Chicory), *Taraxacum* (Dandelion), *Centaurea Cyanus* (Cornflower or Bluebottle), and some acclimatized common weeds, e.g. *Hypochaeris glabra* and *Sonchus oleraceus* (Sowthistle), belong to this tribe, but very few plants indigenous to South Africa.

Other cultivated plants are the Sunflower (*Helianthus annuus*), the Artichoke (*Cynara*), the so-called Jerusalem Artichoke (*Helianthus tuberosus*), the *Scorzonera*, the Daisy (*Bellis*), and Chamomile (*Anthemis nobilis*).

CAMPANULACEÆ.

This order consists of three distinct sub-orders.

Sub-order CAMPANULÆ. **Corolla** mostly gamopetalous, **regular**. **Anthers separate**. **Pollen grains globose, bristly**.

Roella (fig. 251). Capsule opening by a terminal pore.

Wahlenbergia. Capsule opening with valves. 46 species.

Lightfootia. **Corolla** deeply 5 fid or parted to the base. **Filaments broad**. Capsule opening by apical valves.

I.

II.



III.

IV.

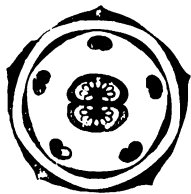
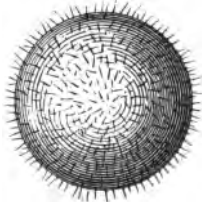


FIG. 251.—*Roella ciliata*. I. Section of flower in its first (male) stage, one stamen removed (†). II. Flower in its second (female) stage (‡). III. Pollen grain. IV. Diagram of flower.

Sub-order LOBELIÆ. **Corolla** gamopetalous, **irregular**, with a split tube. **Anthers cohering**, forming a tube round the stigma. **Pollen grains** ovoid, smooth. Stigma, in its first stage, girt with a circle of hairs.

Lobelia (fig. 252). Flowers blue. 26 species.

Sub-order CYPHIÆ. **Petals 5, free or cohering by their**

claws, spreading irregularly. Anthers free. Pollen grains globose. Stigma knob-like, hollow.

Cyphia. Corolla mostly gamopetalous. Stamens 5, epigy-

I.

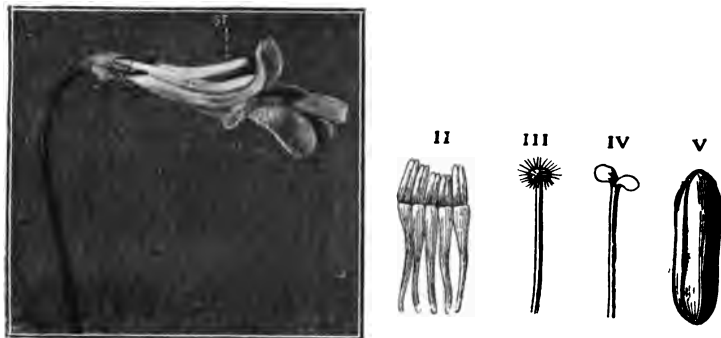


FIG. 252.—*Lobelia coronopifolia*. I. Flower: *st*, staminal column. II. Staminal column split open and flattened out. III. Style and stigma in its first stage. IV. In its second (receptive) stage. V. Pollen grain.

nous; filaments broad based. Ovary inferior, 2 to 10 celled. 20 species, some of them with a tuber.

ERICACEÆ.

Flowers 4-parted. Corolla gamopetalous, limb 4-lobed. Stamens 4 or 8, hypogynous. Anthers usually slightly cohering, opening by terminal pores. Ovary free. Fruit a dehiscent capsule. Shrubs or shrublets with entire, evergreen, mostly narrow leaves in whorls.

There are 10 genera represented in South Africa, of which *Erica* is by far the largest.

Grisebachia. 16 species.

Blaria. 9 species.

Simocheilus (28 species) and several other genera have 4 stamens.

Erica, "the Heaths." Stamens 8; the anthers either terminal or lateral, often crested or tailed at the insertion of the filament. Ovary 4-celled, each cell with 2 or more ovules.

There are about 400 species described, each species mostly

I.

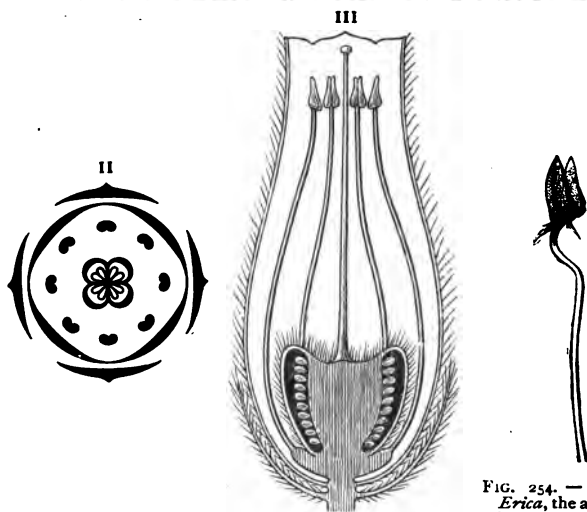


FIG. 253.—I. *Erica cerinthoides*. II. Diagram of flower.
III. One-half of flower.

FIG. 254. — Stamen of *Erica*, the anther opening by pores and bearing two appendages at its base.

confined to a small area, and few only to be found east of Uitenhage.

The genus is divided into 4 sub-genera, and these again into 49 sections.

SCROPHULARIACEÆ.

Structure of flowers somewhat similar to that of the Labiatae. Corolla often **personate** (fig. 142). Ovary free, 2-celled, with many ovules in each cell. Fruit mostly a **capsule**, many seeded.

Nemesia. Corolla personate, the upper lip 4 fid, the lower entire, large, prolonged into a spur or pouch. Anthers 1-celled, mostly cohering in pairs. Many species are annuals

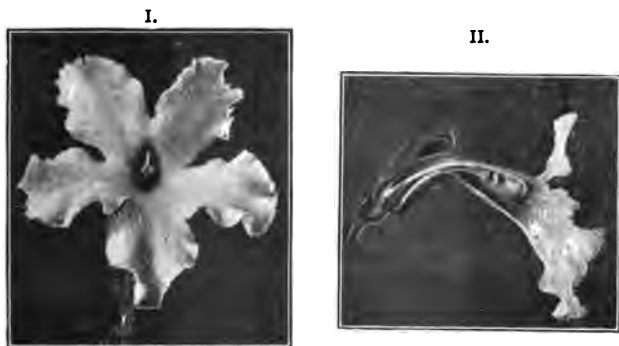


FIG. 255.—*Harveya capensis*. I. Flower seen from the front, showing the knobby stigma. II. Section through flower (not through ovary), showing one short and one long stamen, each with a 1-celled anther.

with a yellow, white, or parti-coloured corolla, often resembling a small *Antirrhinum* (fig. 142).

Nycterinia. Corolla persistent, with a long tube; limb 5-lobed, spreading; lobes often 2 fid. Two stamens fertile, and two with undeveloped or empty anthers. Herbs turning black in drying, with flowers in terminal spikes, mostly white inside and dark outside, opening in the evening.

Chænostoma. Corolla funnel or salver shaped, lobes of limb entire. Stamens 4; anthers 1-celled. Herbs or half-shrubs, much branched.

Lyperia. Corolla with a long, externally viscid tube,

dorsally gibbous or incurved at the apex; limb 2-labiate. The flowers of *L. crocea* are called Cape-saffron (*Geele bloemetjes*).

Manulea. Similar to *Lyperia*, but the corolla-tube is nearly straight at the apex; the throat not dilated; limb 5-parted, lobes nearly equal.

Halleria (fig. 256). Corolla tubular, widening upwards, limb slightly 5 (often only 4) lobed. Stamens 4. Fruit fleshy. *H. lucida* is a small tree or shrub, conspicuous through its dark orange-coloured flowers often appearing on the trunk or old branches.

Hyobanche. Corolla incurved, galeate at the apex; the limb almost obsolete. Stamens 4.

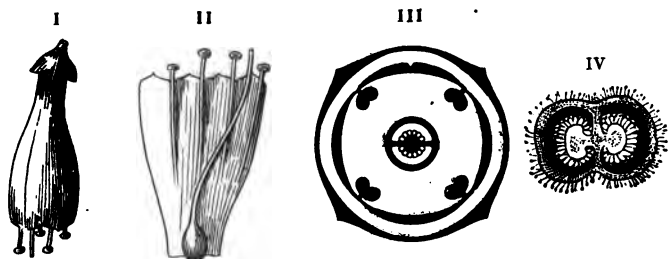


FIG. 256.—*Halleria Lucida*. I. Flower. II. Corolla opened, showing the epipetalous, didynamous stamens. III. Diagram of flower. IV. Bilocular ovary of *Antirrhinum*, with axile placentæ.

H. coccinea is a rosy-red, thick-stemmed, fleshy root-parasite. On Proteaceæ and others.

Harveya (fig. 255). Corolla with a long curved tube, inflated above; limb 5-lobed, ringent. Stamens 4, only one cell of each anther fertile, the other one empty. *H. capensis* is a root-parasite (on Restiaceæ, Grasses, etc.) with showy white or pink flowers, turning black on drying. Common on the mountains of the Western region.

Several other genera allied to *Hyobanche* or *Harveya*, with nearly 30 species, are also root-parasites, some of them occurring only in the Eastern or Northern regions. *Striga* is called by Khama's people the Matabele-flower, because it destroys whole maize-fields if allowed to spread.

Common garden plants are Snapdragon (*Antirrhinum*) and Foxglove (*Digitalis*).

LABIATÆ.

Calyx tubular; corolla bilabiate, upper lip entire or 2 fid, lower 3-lobed. Stamens 4, didynamous (sometimes 2 abortive). Pistil superior; ovary free, deeply 4-lobed, each cell 1-ovuled; stigma 2 fid. Fruit of 4 separable nuts in the base of the persistent calyx.

Aromatic herbs or half-shrubs with 4 angled stems and decussate leaves. Flowers in verticillasters.

Leonotis (fig. 258). Calyx with an oblique 10-toothed mouth. Corolla tube exserted, upper lip concave, elongate, entire, covering the stamens; lower lip 3 fid, lobes subequal, spreading. Upper lobe of style very short. *L. Leonurus* (wild dagga) with bright scarlet, velvety flowers. The leaves are smoked by natives like Indian hemp.

Stachys (fig. 110). Calyx 5-toothed. Upper lip of corolla short, lower mostly longer, its medial lobe larger than the lateral ones. Style branches almost equal.

Mentha (Mint) (fig. 257). Flowers nearly regular. A few species wild along water-courses; some cultivated, e.g. peppermint.

Salvia (Sage) (fig. 176). Corolla large, its tube mostly widening upwards, upper lip erect, lower spreading, the middle lobe larger. Stamens 2, with short filaments and long branched connectives; one cell of each anther developed only. Herbs or shrubs (*S. aurea*) with strongly scented leaves.

S. africana with blue flowers common throughout the country. *S. officinalis*, the garden Sage.



FIG. 257.— Nearly regular flower of Peppermint (*Mentha piperita*).

THYMELEÆ.

Flowers bisexual. Perianth simple, formed by the corolloid calyx, which is tubular, mostly 4-parted (sometimes 5), generally provided with 4 or 8 scales or other appendages.

I

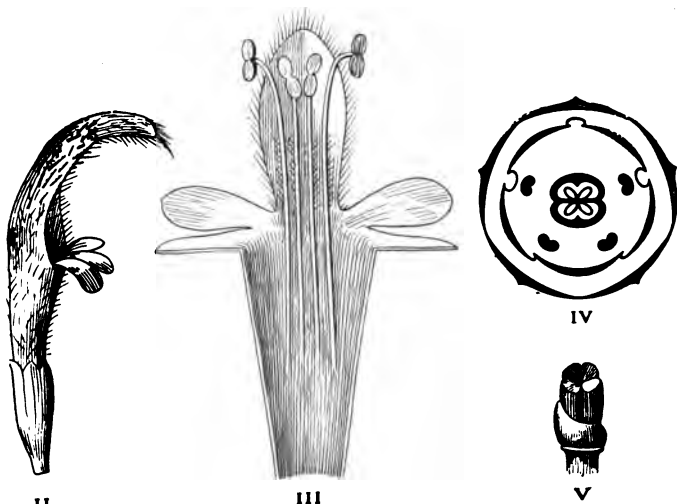


FIG. 238.—*Leonotis Leonurus*. I. Flowering branch. II. Flower. III. Corolla opened. IV. Diagram of flower. V. Fruit. (All nat. size.)

Stamens 4 or 8, rarely 10, inserted in the calyx-tube. Ovary free. Fruit a nut or drupe.

Shrubs with simple, entire, exstipulate leaves. Bark very tough, burning the mouth when chewed.

Struthiola (fig. 259). Calyx-tube slender, jointed above the ovary, the throat widened; limb regular, 4-parted; cylindrical scales 8 or 12 (rarely 4), inserted on the rim of the throat,

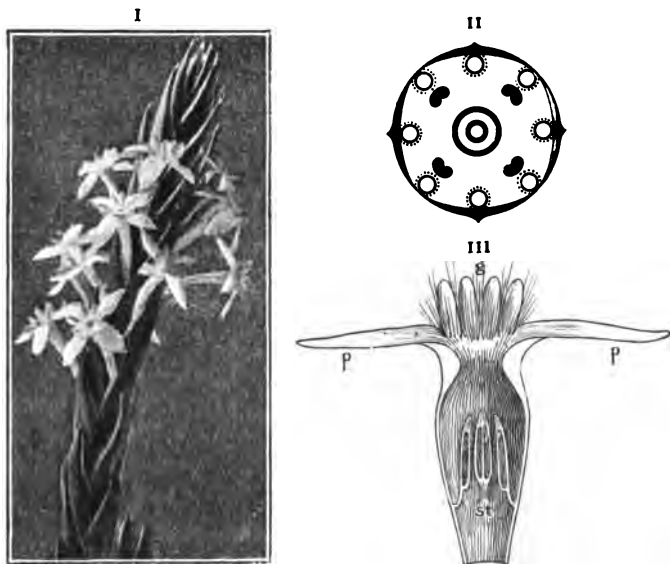


FIG. 259.—*Struthiola virgata*. I. Flowering branch ($\frac{1}{2}$). II. Diagram of flower. III. Median section through upper part of flower, showing 2 entire perianth lobes (*p*), 4 glands (*g*), 1 complete and 2 halved stamens (*st*).

each girt with a circle of hairs. Anthers 4, subsessile, alternate with the calyx-lobes, included. Heath-like shrubs with slender branches. Flowers in terminal, leafy spikes, mostly white or creamy, often sweetly scented.

Gnidia. Differs from the preceding genus principally by: stamens 8, in 2 whorls, the anthers of the upper whorl half-exserted. Flowers mostly capitate, white or yellow.

Lachnaea. Similar to the preceding genera, but stamens 8, with conspicuous filaments; scales 8, inserted below the stamens.

Passerina. Calyx without scales. Stamens 8, with subulate, exserted filaments. Shrubs with decussate heath-like leaves. Of common occurrence.

Chymococca differs from the preceding genus by its fruit (a berry). *Ch. racemosa* is common in sand-dunes along the coast. Branches drooping; berries pulpy, red (Dronk besjes).

PROTEACEÆ.

Perianth simple, formed by the coloured calyx, 4-parted

A

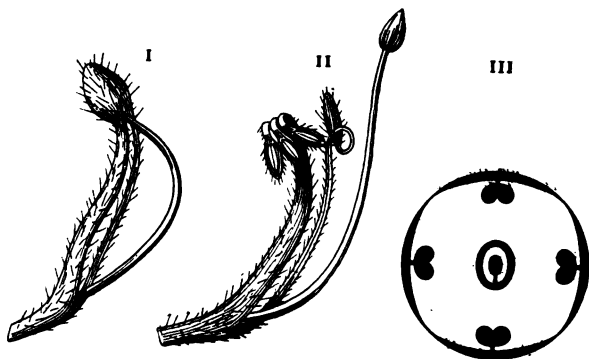


FIG. 260.—A, *Leucospermum ellipticum*. Flower head ($\frac{1}{2}$). *Leucospermum conocarpum*. I. Flower-bud. II. Flower opened, showing 3 of the 4 anthers. III. Diagram of flower.

or 4-cleft, mostly irregular. Stamens 4, inserted on the calyx-lobes. Ovary free; style simple. Fruit an achene or nut.

Trees or shrubs or under-shrubs. Flowers mostly capitate.

This order is largely represented in South Africa and Australia. About 200 species occur in our South-Western region, a few only being found further east or north-east, e.g. Eastern Transvaal, Mashonaland, etc.

Protea (fig. 262). Flowers bisexual, capitate. Involucre formed of persistent, coriaceous, imbricate bracts, often coloured



FIG. 261.—*Brabejum stellatifolium*.



FIG. 262.—Tailed achene of *Protea mellifera*.

or bearded. Calyx elongate, irregular, three of its lobes cohering, the fourth separating at the opening of the flower. Anthers sessile in the spoon-shaped apices of the perianth-lobes. Stigma subulate. Fruit an achene, tailed by the persistent style and covered with rigid hairs. The most conspicuous species are *P. mellifera* (Sugar-bush); *P. grandiflora* (Waageboom), a tree of considerable size; *P. cynaroides*, with flower-heads often

measuring eight inches in diameter; *P. nana*, with beautiful hanging, dark red heads; *P. lepidocarpon*, with involucre-scales tipped with black soft hairs, etc.

Leucospermum (fig. 260). Similar to *Protea*, but receptacle paleaceous; only the lobes of calyx separating, their claws (3)

I

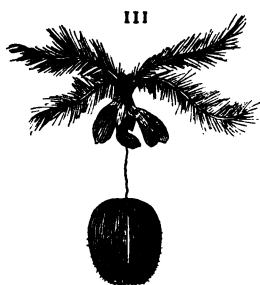


FIG. 263.—*Leucadendron argenteum*. I. Male inflorescence ($\frac{1}{4}$). II. Single flower with barren style ($\times 2$). III. Nut with persistent style and calyx, the latter split at its base and prevented from slipping off by the knobby stigma.

cohering. Style deciduous; stigma thickened. Fruit a subglobose, smooth nut. *L. conocarpum* (Kreupelhout), with yellow flowers and hairy whitish leaves, is common.

Mimetes. Flower-heads mostly few-flowered in the axils of the leaves towards the end of the branch. Involucre

membranous. Calyx regular, the segments distinct. Shrubs similar in habit to *Leucospermum*. *M. hirta* is a common tree. The bark of this species and of other Proteaceæ used for tanning.

Leucadendron (fig. 263). Flowers diœcious, both kinds in terminal, involucreted heads. Involucre formed by the upper leaves, mostly yellow. Calyx subregular, all 4 claws cohering. Male flowers with a sterile style; female head developing into a cone. Fruit a nut, mostly flat and winged or subglobose, as in the Silver-tree. *L. argenteum* (Silver-tree) occurs only on the Cape Peninsula, near Paarl and Stellenbosch.

Brabejum stellatifolium (fig. 261), Wild Almond, is common along streams.

Some Australian species are quite acclimatized; e.g. *Haakea suaveolens*, for hedges, and *Grevillea* as an ornamental tree.

AMENTACEÆ.

This order is represented in South Africa only by a few indigenous plants, viz. the Cape Willow (*Salix capensis*), which adorns the banks of the Vaal and other rivers; and the genus *Myrica*, of which *M. cordifolia* and others supply the berry-wax. Introduced trees are the Oak, Poplar, Chestnut, Walnut.

Trees or shrubs with monœcious (e.g. Oak) or diœcious (e.g. Willow) flowers. Male flowers in catkins. Cultivated are the Oak, Willow, Poplar, Chestnut, Walnut.

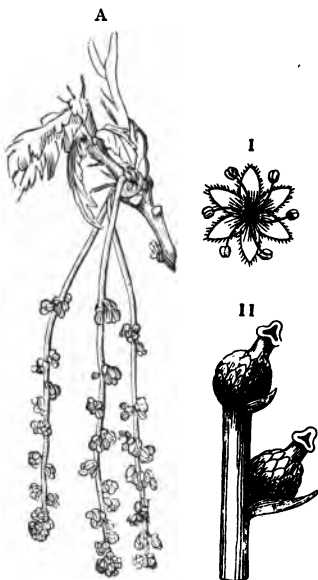


FIG. 264.—A, Catkin or amentum of the Oak. I, Male flower of Oak. II, Female flowers. (Both $\times 3$.)

CONIFERÆ.

Gymnospermous (p. 105). Flowers unisexual. Male : several or many stamens arranged on a deciduous axis, the whole **resembling a catkin** ; mostly many flowers together, forming a spike (fig. 265, I.). Female : **a scale which bears the naked ovules** (fig. 265, III.). Scales mostly close together,

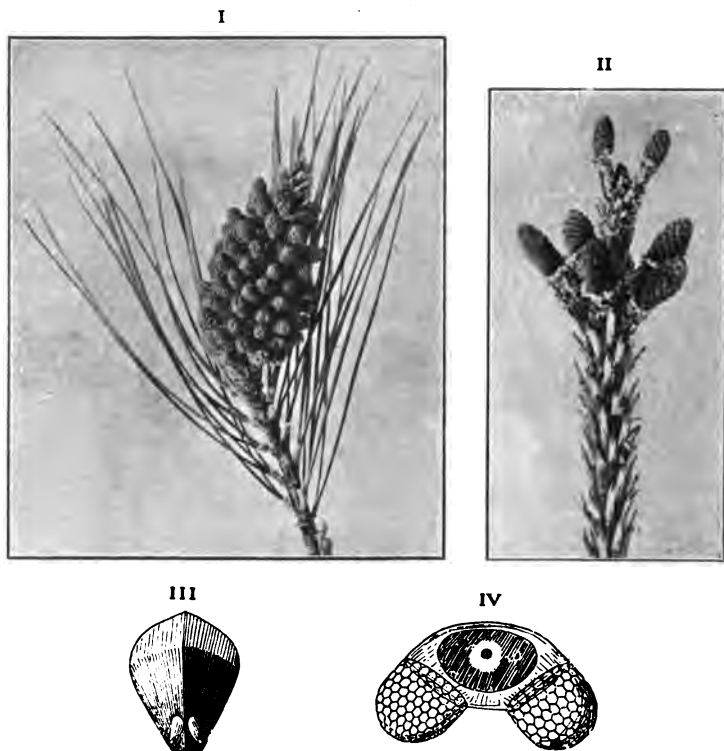


FIG. 265.—*Pinus Pinea*. I. Male branch, showing the catkin-like inflorescences arranged in a spike. II. Female branch with several spikes. III. Scale of female spike with 2 ovules (magnified). IV. Pollen grain.

finally forming a cone. Seed with a hard crustaceous coat ; embryo in the axis of the albumen ; **cotyledons 2 or more**.

Trees or shrubs with resin in leaves and stems.

Sub-order *Abietinæ*. Represented in South Africa only by imported plants, viz. Pines and Firs. Monœcious. The female inflorescence forms a cone. Ovules anatropous, 2 on each scale (fig. 265, III.).

Sub-order *Cupressinæ*. Dioecious.

Cupressus juniperoides (Clanwilliam Cedar). Ovules orthotropous, many on each scale. Cone 4-valved, each valve (scale) with 5 to 10 seeds at its base. This beautiful tree formerly formed extensive forests on the Cedar Mountains, but small patches of it only are left at present.

Sub-order *Podocarpeæ*. Dioecious.

Podocarpus (fig. 267). Ovules solitary, or mostly so, in a lax, few-flowered spike. The bracts and rachis develop into a fleshy receptacle, crowned by the seed (mostly 1, rarely 2). Nearly allied to the European Yew (*Taxus*).



FIG. 266.—Cone of the Scotch Fir.



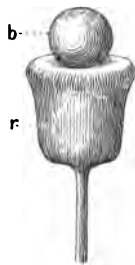
I



II



III



IV

FIG. 267.—*Podocarpus elongatus*. I. Male branch ($\frac{1}{4}$) with 3 spikes. II. Female inflorescence ($\times 3$). III. Section through the latter, showing one ovule. IV. Ripe pseudocarp: r, fleshy receptacle; b, seed enclosed in green resinous scale.

P. Thunbergii (True Yellow-wood), with lanceolate shining leaves. Receptacle dark blue, sweet, size and colour of a damson.

P. elongata (Outeniqua Yellow-wood). Leaves narrower. Receptacle smaller, bright crimson. This is the largest indigenous tree, common in the Knysna and Eastern forests, the "Eastern Monarch," in the Amatola, measuring 80 feet in height, with a girth of 23 feet.

Two other gymnospermous orders are represented in South Africa, viz. Cycadaceæ, by the genus *Encephalartos* (Kafir Bread), and Gnetaceæ, by the most singular of plants, the *Welwitschia mirabilis*. Stem woody, up to 3 feet diameter, at its upper end, which just projects above the ground. The two permanent leaves last the whole lifetime of the plant, growing at their base continually, and reaching a length of 6 feet.

ORCHIDACEÆ.

Flowers bisexual, irregular; perianth limb 6-parted. The three outer segments, called sepals, coloured, and the odd one usually (by a twist in the ovary) uppermost; inner segments, called petals, unequal; the two lateral similar, the odd one (labellum or lip), unlike the others, often lobed or spurred. **One fertile stamen only**; anther large, mostly 2-celled; **pollen cohering in waxy masses** (fig. 269). Ovary 1-celled, with 3 parietal placentas; **style combined with the filaments** and other parts into the "column," which bears the viscid stigma in front.

The upper part of the column, the **rostellum**, generally bears the gland or glands to which the caudicles of the pollinia are attached.

Herbaceous plants with simple leaves, either terrestrial, and then mostly with tuberous roots, or epiphytic. Nearly 400 species are known from South Africa.

Tribe VANDEÆ. Anther lid-like, deciduous.

Eulophia. Perianth expanded, the segments subequal; lip spurred or saccate at base, usually 3-lobed, and furnished with crested or bearded longitudinal ridges. Terrestrial.

Mystacidium (fig. 121). Perianth spreading with subequal segments; lip with a very long filiform spur. Caulescent epiphytes of the Eastern forests and Natal.

Tribe OPHRYDEÆ. Anther without a lid, cells distinct; pollen masses granular, numerous, united into one pollinium in each anther cell, each pollinium terminating in a true caudicle.

Disa (fig. 268). Odd sepal helmet or funnel shaped, spurred or saccate at base, the two side sepals spreading; lips free, filiform or dilated, spurless, much smaller than the

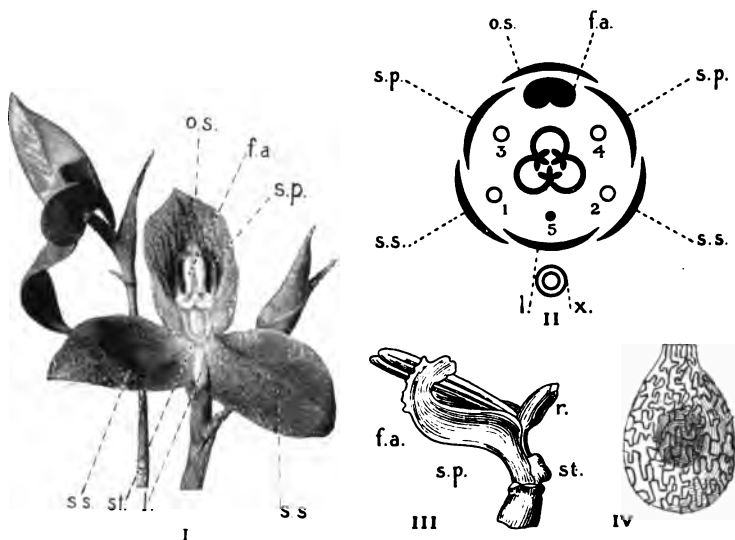


FIG. 268.—*Disa uniflora*. I. Two flowers and one bud. II. Diagram of flower. In specimens with more than one flower the lip (*l*) is turned away from the stem (*x*) through a twist in the ovary. III. Column (side view) with anther and two lateral petals: *st*, stigma; *r*, rostellum; *1*, *2*, *3*, *4*, undeveloped or greatly modified stamens; *x*, stem of plant; *ss*, side sepals; *os*, odd sepal; *sp*, side petals; *l*, odd petal (labellum); *fa*, fertile anther. IV. Seed ($\times 20$).

side sepals; side petals small, erect. Anther 2-celled. Flowers in racemes or spikes. A large genus of about 100 species, including at present, on the authority of Mr. Bolus, the former genera, *Schizodium*, *Monadenia*, *Penthea*, and *Herschelia*.

Disperis. Perianth hooded, the odd sepal cohering with the side petals into a "galea;" side sepals saccate, spreading; lip clawed, adnate to the face of the column; the rostellum produced in front into two cartilaginous arms.

Satyrrium. In this genus the ovary is not twisted, hence the odd sepal not uppermost. Perianth ringent, the lower portion formed by the subsimilar sepals and side petals; the

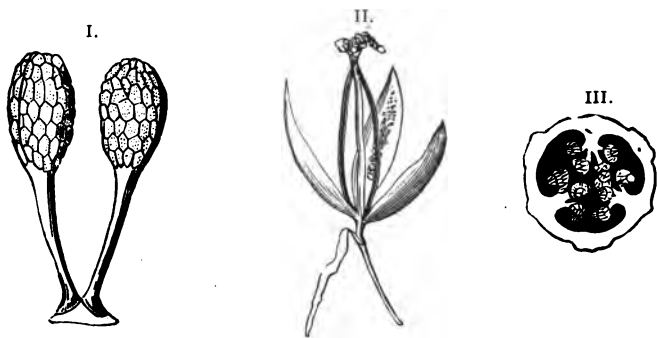


FIG. 269.—I. Pollinia of an Orchid, with their pedicels united by the rostellum. II. Burst capsule. III. Transverse section of an ovary.

upper portion by the helmet-shaped labellum, which is 2-spurred or 2-saccate. About 40 South African species, some of these with racemes of flowers two feet high.

IRIDEÆ.

Perianth tubular, often irregular; limb 6-parted. **Stamens 3**, opposite the outer segments of the perianth; anthers 2-celled, opening outwards. **Ovary inferior, 3-celled**; ovules numerous; style 1; stigmas 3, of different structure. **Capsule 3-celled**, opening loculicidally.

Herbs, mostly with corms, equitant leaves, and showy flowers. The stigmas form good characters for the subdivisions.

Moræa (fig. 270). Perianth-tube short; limb spreading, the inner segments smaller. Filaments distinct. Stigmas petaloid, 2 fid.

Many species with brilliant but fugacious flowers. The corms of several species, e.g. *M. edulis*, are eaten (Uintjes).

Babiana. Perianth-tube long, gradually expanding into a funnel-shaped, irregular, ringent limb. Stamens in the throat. Stigmas cuneate, folded, entire.

Gladiolus (fig. 271). Perianth-tube curved, widening

upwards; limb unequal, ringent. Stigmas cuneate, dilated, entire. Seeds flat, winged. Many species.

Antholyza. Perianth-tube suddenly swelling into a wide throat. Seeds large, subglobose, not winged.

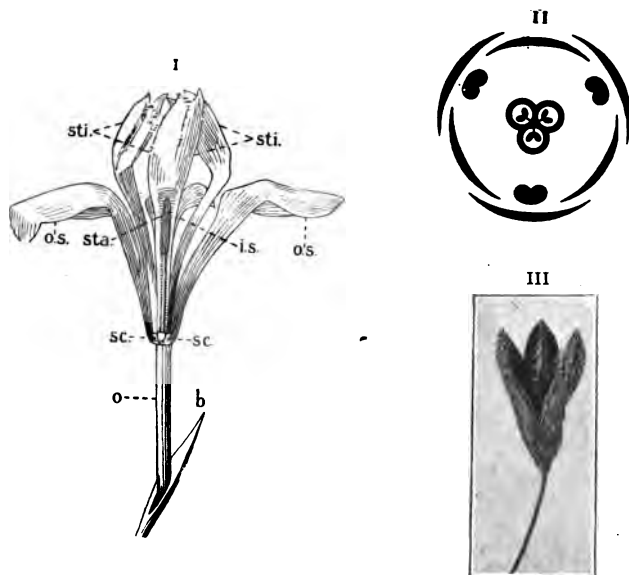


FIG. 270.—*Morrea edulis*. I. Flower after removal of one outer and two inner segments of perianth: *os*, outer segments; *is*, inner segment; *sta*, stamen; *sti*, petaloid stigmas; *sc*, scars of removed segments; *o*, ovary; *b*, bract. II. Diagram of flower. III. Loculicidal capsule of *Morrea edulis*, Ker.

Watsonia (fig. 272). Perianth similar to that of *Gladiolus*. Stigmas linear, 2-parted, the lobes filiform.

Sparaxis. Perianth-tube short, widening into a funnel-shaped, mostly subregular limb. Stigmas wedge-shaped, channelled, entire.

Iria. Perianth-tube long and slender, with a regular, salver-shaped limb. Stigmas narrow-linear, recurved.

Hesperantha. Perianth-tube slender, with a regular, spreading limb. Stigmas filiform, very long, spreading.

Flowers sweetly scented, dull coloured on their outer side, opening in the evening ("Avond-bloemetjes").



FIG. 271.—*Gladiolus angustus*.
Flower.



FIG. 272.—*Watsonia humilis*.
Flower.

Trichonema. Perianth-tube short, with a funnel-shaped, spreading, regular limb. Stigmas linear, 2-parted.
Fruits eaten by children ("Frutang").

AMARYLLIDÆ.

The flowers of the plants of this order are very similar to those of the Liliaceæ, but possess an inferior ovary. The floral diagram of both orders is the same.

Amaryllis. Perianth bell-shaped, with a very short tube, the segments being nearly free. Stamens attached to the edge of the tube, unequal; anthers versatile. *A. Belladonna*, from the South-Western region, is largely cultivated. The flowers of this and other allied plants appear before the leaves.

Nerine (fig. 273). Segments of perianth quite free, narrow, spreading, and recurved. Stamens very long. Stigma (in its second stage) 3 fid. *N. Sarniensis*, the Guernsey Lily, is common on the mountains of the Western province.

Hæmanthus. Flowers in umbels, with an involucre of broad,

fleshy, coloured bracts. Scape flat, mostly mottled. Leaves large, flat on the ground, 2 or more.

Brunsvigia (Candelabra flowers). Perianth with a tube curving upwards. Plants with very large bulbs. Flowers in umbels, sometimes two feet in diameter.

Hypoxis. Perianth starlike, its segments quite free. Bulbous plants, with radical leaves. Scapes mostly 1-flowered. Flowers white or yellow, dark outside.

Gethyllis. Perianth-tube filiform, very long, with a spreading limb. Stamens, 6 or 12 or 18; anthers basifixed. Fruit a succulent, strongly scented berry (Kukumakranka).



FIG. 273.—*Nerine sarniensis*. Herb.

Several other beautiful plants belonging to this order have been taken into cultivation here and in Europe, e.g. *Vallota* (Knysna-lily), *Crinum*, *Cyrtanthus*. The Agave (*A. Americana*), with leaves resembling those of some Aloes, thrives here as well as in its native country, and supplies fodder for cattle in times of drought, as well as fibre for ropes.

LILIACEÆ.

Flowers regular. Perianth corolloid; segments in 2 rows of 3 each, free or united. Stamens 6; anthers introrse, 2-celled. Ovary superior, 3-celled; stigma simple or rarely 3-parted. Fruit a 3-celled capsule, opening loculicidally.

This order is largely represented in South Africa, comprising trees, shrubs, and herbs, the latter often bulbous.

Ornithogalum (fig. 274). Segments of perianth nearly free, spreading, the inner slightly smaller than the outer ones. Stamens at the base of the segments of the perianth; filaments

flattened, the 3 inner sometimes winged. Scapigerous, bulbous plants.

Lachenalia. Segments of perianth lying close together, forming a tube. Bulbous, scapigerous plants with racemose inflorescence. Flowers mostly pendulous, showy.

Aloe (fig. 275). Perianth subcylindrical, straight or curved, the segments more or less connate, the 3 inner narrower and

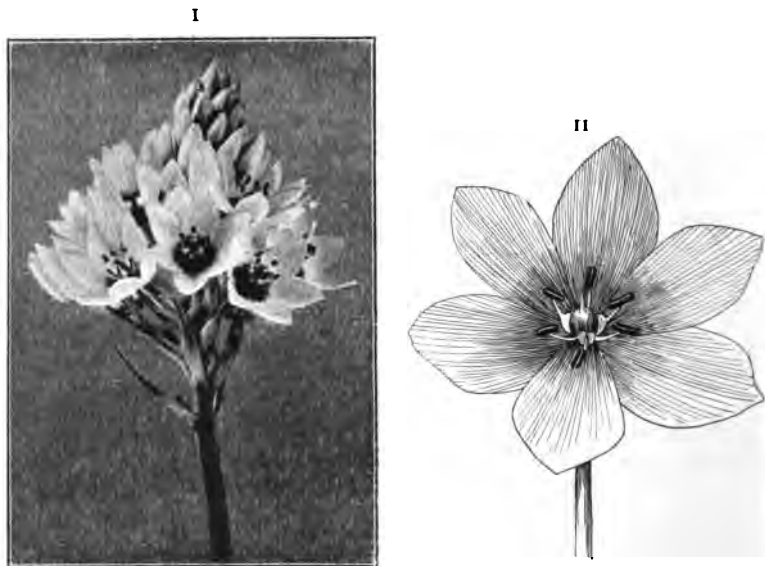


FIG. 274.—*Ornithogalum thyrsoides*. I. Raceme($\frac{1}{3}$). II. Flower. The filaments of 3 stamens are winged at their base.

thinner than the outer ones. Stamens hypogynous, mostly included in the tube. Ovary sessile, with numerous ovules.

Shrubby or arborescent, succulent plants with bitter juice, mostly found in the dry districts. Over 150 species described. The leaves of some species (e.g. *A. ferox*) are used for the manufacture of the commercial Aloe.

Several other indigenous Liliaceæ with showy flowers are cultivated in gardens, e.g. *Agapanthus*, *Eucomis*, *Chlorophytum*, *Albuca*.

The Tulip, Lily of the Valley, Asparagus, Onion (*Allium Cepa*), and Garlic (*A. sativa*), also belong to this order. Some indigenous species of *Asparagus* are used as

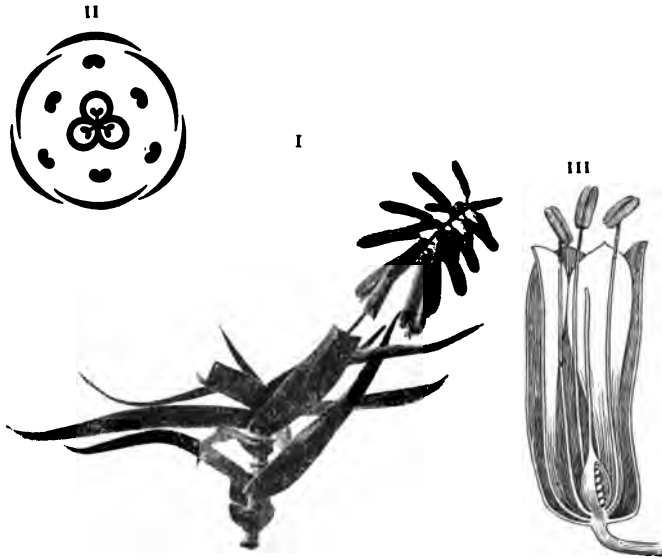


FIG. 275.—*Aloe ciliaris*. I. Flowering branch. II. Diagram of flower. III. Section of flower.

vegetables; some are known as “Wacht een bietje.” Their so-called leaves are modified branches, botanically known as “phylloclades.”

RESTIACEÆ.

Flowers **diœcious**. Perianth consisting of 6 dry segments (glumes) in 2 rows. Male flowers with 3 **stamens**, opposite the inner glumes; filaments slender; anthers dorsifixed, versatile, introrse, exserted, 1-celled, dehiscing longitudinally. Female flower: ovary 1 to 3 celled, **ovules solitary**, pendulous; styles 1 to 3. Fruit a capsule. Perennial herbs with rhizomes and rush-like culms. Flowers mostly in spikelets which form spikes, panicles, or fascicles.

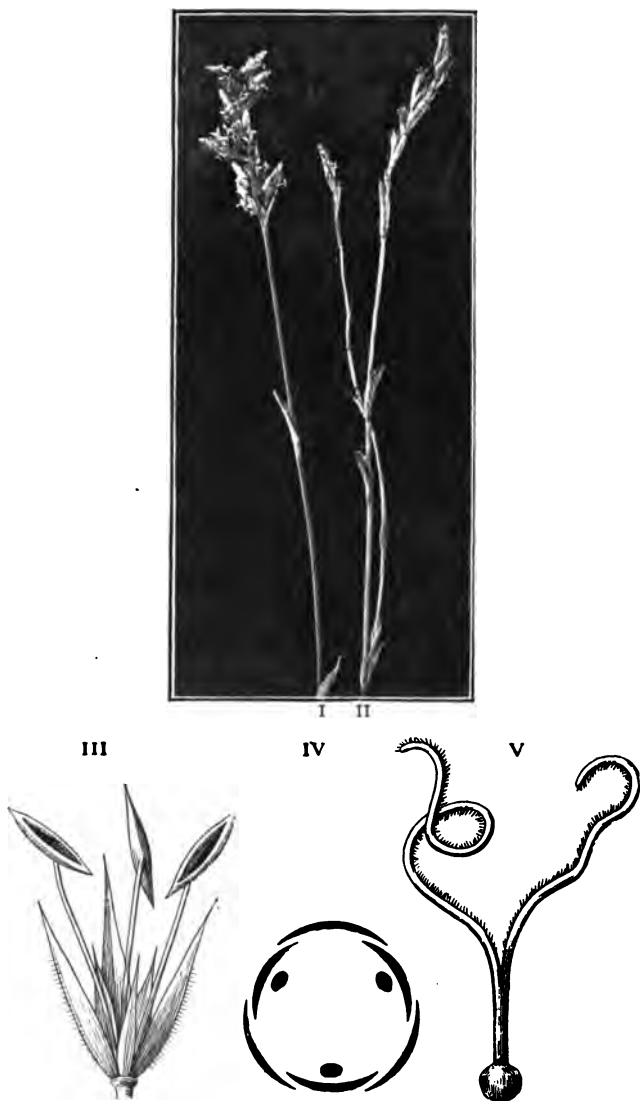


FIG. 276.—*Restio cuspidatus*. I. Male culm (†). II. Female culm (†). III. Male flower (×4). IV. Diagram of male flower without bracts. V. Pistil from female flower (×4).

This order is, with the exception of a few species, confined to Australia and South Africa, here occurring almost



FIG. 277.—*Dovea mucronata*. I. Fructiferous culm ($\frac{1}{2}$). II. Ripe capsule split open (magnified): s, seed in front cell.

only in the South-Western region, and covering large tracts of country. The true rushes (Juncaceæ) form an insignificant portion of the vegetation of this region, one species only, viz. *Prionum palmita* (the Palmiet), being remarkable.

Restio (fig. 276). Characters of the order. Ovary 2 to 3 celled; style 1, with 2 or 3 stigmas. Capsule 1 to 2 celled. Sheaths of culm persistent. About 80 species.



FIG. 278.—*Elegia verticillaris* ($\frac{1}{2}$).

Dovea (fig. 277). Principally differing from *Restio* by its deciduous sheaths. *D. tectorum*, common in the Cape flats, largely used for thatching.

Thamnochortus. Subsimilar to *Restio*, but fruit 1-seeded, indehiscent.

Elegia (fig. 278). Similar to *Dovea*, but fruit 1-seeded, indehiscent.

Several species of Restiaceæ are gathered and exported as so-called "Cape grasses," i.e. *Elegia*, *Thamnochortus*, *Hypodiscus*, *Cannamois*.

CYPERACEÆ.

Flowers arranged in spikelets, consisting of several scale-like bracts, called glumes, arranged alternately along an axis. Each glume, or the upper ones only, with a solitary flower in



FIG. 279.—Flower of *Cyperus longus*, with the parts separated.

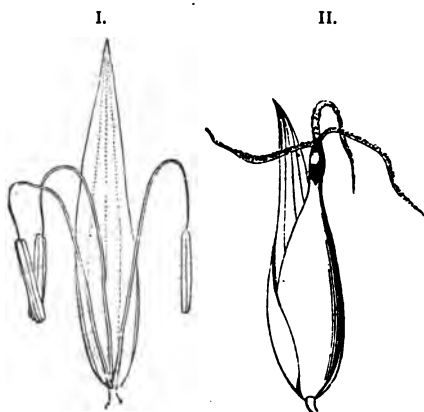


FIG. 280.—I. Male flower, II. Female flower, of *Carex*.

its axil. Perianth absent, or represented by bristles or scales. Stamens 3; anthers basi-fixed, 2-celled. Ovary 1-celled; stigmas 2 or 3. Fruit an achene.

Tufted or creeping-rooted plants with solid culms; leaves with entire sheaths. The true "sedges."

Cyperus. Glumes distichous. *C. esculentus* forms little

tubers, eagerly collected by the natives of the northern regions; *C. textilis* (Matjesgoed) is largely used for mats and baskets; while *C. bulbosus* (Nut-grass) is an obnoxious weed, too well acclimatized.

Ficinia, with numerous Cape species, and *Scirpus* are easily distinguished from *Cyperus* by the glumes being imbricated on all sides.

Carex (figs. 83, 280) has mostly monoecious flowers. A vast cosmopolitan genus with a few Cape species.

GRAMINACEÆ.

As an illustration of this order, we may take the Oat plant (*Avena sativa*). The flowers are arranged in spikelets, which form a panicle (in wheat a spike). Each spikelet consists of two outer bracts (glumes), enclosing several flowers, which are either fertile or barren. Each fertile flower is enveloped by two scales, one with a prolongation or *awn*, *a* (fig. 282), the flowering *glume*, or *outer pale*; the other, *pi*, more delicate, the *inner pale*. Within these there are two minute scales, feathery above, the *lodicules*. These represent all there is of the perianth (see fig. 282, II.); then three stamens with *versatile anthers*, and, lastly, a single ovary with *two feathery stigmas*.

This is the general structure of the plants of the order; there are, however, minor points of deviation. Thus, in the Rye-grass (*Lolium*) there is only one outer glume to each spikelet, and in *Leersia* there is none. In the Rice there are 6 stamens, and the Maize has monoecious flowers, its female flowers possessing one stigma only (long, thread-like).

This large and wide-spread order is one of the most important to man, yielding, as it does, the various cereals that he employs as food, and the Grasses used as food for cattle. Amongst the cereals the first place must be given to Wheat (*Triticum vulgare*). The origin of this important plant is entirely lost in the past. We are not acquainted with the wild stock from which it has been produced. Numerous varieties of Wheat are cultivated, some with awns to the flowering glumes and some without. By choosing the best ears and

grains, and using these for sowing, and by repeating this process several times, the Wheat is greatly improved in character. By this process of artificial selection what is known as "Pedigree Wheat" is obtained. The seeds of all the Gramineæ are albuminous, and flour is obtained from the crushed albumen.

Barley (*Hordeum vulgare*) is another important cereal, probably one of the first cultivated. Malt is prepared from Barley by allowing it to begin to germinate, and then heating it to

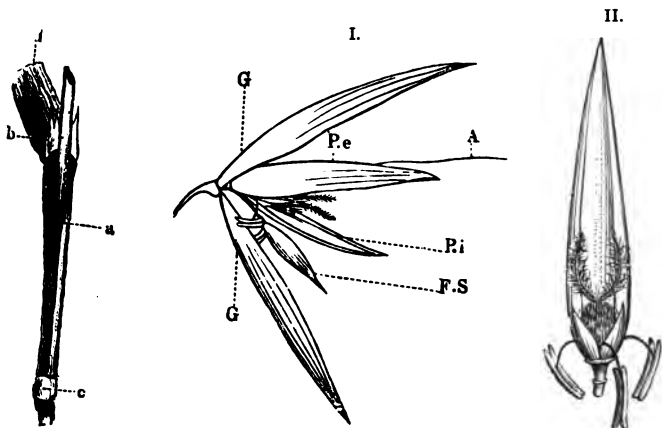


FIG. 281.—*a*, Split leaf-sheath of a Grass; *b*, ligule; *d*, part of the lamina of the leaf; *c*, node of the culm.

FIG. 282.—I. Expanded spikelet of the Oat, with a fertile and a barren flower, *FS*; *G*, glumes; *Pe*, outer pale, with awn, *A*; *Pi*, inner pale; within are the feathery stigmas. II. Fertile flower with the outer pale removed.

160° or 180°; by this means the starch of the grain is converted into sugar, which is capable of fermentation.

Oats (*Avena sativa*), Rye (*Secale cereale*), and Millet, which is obtained from several genera, are also cultivated. Indian Corn (Maize) is obtained from *Zea Mais*, which is a native of the New World. Rice is obtained from *Oryza sativa*, a tropical plant, and Sorghum (Kaffir Millet) from *S. vulgare* and *S. Durrha*.

Besides these food-plants, we have the important Sugar-cane (*Saccharum officinarum*), the clarified juice of which yields us sugar, whilst the residue produces molasses and treacle.

Numerous Grasses are grown for fodder purposes; and the common reed (*Phragmites communis*), a cosmopolitan plant, serves as thatching material here as well as in Europe.

Many grasses indigenous to South Africa share in the formation of the rich pasturage of the Northern and Eastern regions; e.g. the Dwa-grass or Toa-grass (*Aristida Lichtensteinii*). Their mode of growth is quite different from that of the English fodder-grasses. They grow in tufts, not in the form of a turf, and often form vast waving grass-fields extending over hundreds of miles.

Stenotaphrum Caffrum, the so-called coarse "kweek," is the only grass suitable for lawns which cannot be irrigated during the dry summer of the Western districts.

It will be well, in conclusion, to point out the differences between the two allied orders, Cyperaceæ and Graminaceæ, in a tabular form.

*Cyperaceæ.**Graminaceæ.*

Stem solid.	Stem hollow.
Leaf-sheaths entire.	Leaf-sheaths split.
No ligule present.	Ligule present.
No lodicules.	Lodicules generally present.
Anthers innate.	Anthers versatile.
Stigmas three, simple.	Stigmas two, feathery.

PLAN FOR DESCRIBING A PLANT.

Root.—Kind.

Stem.—(a) Kind (herbaceous, shrubby, or woody).

(b) Shape (rounded, angular, square, ribbed, etc.).

(c) Direction (upright, spreading, creeping, climbing, etc.).

(d) Surface (smooth, hairy, rough, etc.).

Leaves.—1. Insertion (opposite, alternate, radical, etc.).

2. Petiole (presence or absence, peculiarities).

3. Lamina.

- (a) Composition (simple or compound).
- (b) Venation.
- (c) Margin.
- (d) Incision.
- (e) Apex.
- (f) General outline.
- (g) Surface (smooth, hairy, etc.).

4. Stipules (present or absent, shape, if present ; also note if sheath).

Inflorescence.—Kind of inflorescence and bracts.

Flower.—1. Calyx.

- (a) Cohesion (gamosepalous or polysepalous).
- (b) Number of sepals or divisions.
- (c) Adhesion (inferior or superior).
- (d) Specialities (colour, shape, etc.).

2. Corolla.

- | | |
|------------------|-------------|
| (a) Cohesion | } As above. |
| (b) Number | |
| (c) Adhesion | |
| (d) Specialities | |

Note.—If perianth is present, describe it in same manner.

3. Corona or other appendages between corolla and androecium should be described here.

4. Androecium.

- (a) Cohesion (free, monadelphous, etc.).
- (b) Number.
- (c) Adhesion.
- (d) Specialities (if tetradynamous or didynamous ; also peculiarities of filament and anther).

5. Gynœcium.

- (a) Cohesion (syn- or apo-carpous).
- (b) Number of carpels.

- (c) Adhesion (inferior or superior).
- (d) Peculiarities of ovary, including—
 - α. Number of cells.
 - β. Placentation.
 - γ. Number of ovules.
- (e) Peculiarities of style and stigma.

Fruit and Seed.

EXAMPLE.

SWEET VIOLET (*Viola odorata*).

Root.—Fibrous.

Stem.—Slightly shrubby, rounded, short, underground, forming a rhizome ; surface scarred.

Leaves.—Apparently radical, but really growing in a tuft at apex of stem. *Petiole* evident, covered with short scattered hairs. *Lamina* simple, net-veined, unicostate, curve-veined, crenate margin, apex either rounded or somewhat acute, cordate or reniform, surface hairy, especially upon the margins and veins. *Stipules* present, slightly membranous, undivided, lanceolate.

Inflorescence.—Single-flowered, the flower-stalks growing from the axils of the leaves and bearing two small nearly opposite linear bracts about the centre.

Flower—

Calyx.—Polysepalous ; five sepals, inferior, irregular, each sepal broad in centre and pointed towards the two extremities, green, hairy.

Corolla.—Polypetalous ; five petals, hypogynous. Irregular, either purple or white ; in the former case the lower petal has several darker lines converging towards interior of flower ; the lateral petals have a hairy tuft near mouth of tube ; the inferior petal is prolonged into a short blunt spur.

Andræcium.—Stamens free, five in number, hypogynous, almost sessile, the filament being very short ; connective prolonged beyond the anthers as an orange-

coloured mass ; two of the stamens spurred, the spurs passing into the spur of corolla.

Gynæcium.—Syncarpous, three carpels, superior ; ovary 1-celled, with three parietal placentas and numerous ovules ; surface of ovary hairy ; style curved ; stigma hooked.

CHAPTER XVIII.

BOTANICAL REGIONS OF SOUTH AFRICA.

As the vegetation of a country largely depends upon the rainfall and the climate generally, and as there is a great variety of climates in South Africa, it is easy to understand why the various regions of this country differ so much in their flora. The climate of the South-Western districts, with their winter rains, is quite different from that of the Central and Northern tablelands, which receive their rain in summer; and both, again, differ considerably from the South-Eastern and Eastern coast-lands, where the climate becomes more and more sub-tropical the further one proceeds northwards.

These climatic regions also constitute fairly well-defined floral regions, viz. the South-Western Region, the South-Eastern Region, the Central Region (lower and upper Karoo), and the Northern or Kalahari Region.

The extent of these regions is easily recognized on the sketch-map, but it must be borne in mind that only some of the boundaries are well defined, while in other parts, *e.g.* in the Eastern province, two or three floras gradually verge into each other.

1. **The South-Western Region.**—The vegetation of this region is characterized by the dominating development of several otherwise inconspicuous orders. Foremost among them are the Ericaceæ, Proteaceæ, Restiaceæ, and Rutaceæ, represented by a total of about 1000 species, while only a few stragglers of these orders occur in other parts of South Africa. Several other orders, *e.g.* Irideæ and Orchideæ, and several genera of other orders, *e.g.* *Oxalis* and *Pelargonium*, contribute

largely to its peculiar vegetation, which is the same in composition in the plains as on the highest mountains, the species, of course, being mostly different in different localities.

In the greater part of this region trees occur only in the ravines of the mountains, with the exception of the famous Silver-tree, which is confined to the Cape Peninsula and some adjoining localities, and the Cape Cedars in the Cedarbergen. More eastward, however, in the districts of Knysna and Zitzikamma, beautiful forests exist with gigantic trees: Yellow-wood (*Podocarpus*), Stink-wood (*Ocotea*), Assagai (*Curtisia*), Olives, etc.

A peculiar feature of the vegetation of this region is that the period of rest for many plants is the summer. After the first autumn rains the dormant vegetation awakens. Flats and hills become green within a few weeks, and numberless flowers (*Oxalis*, *Amaryllideæ*, *Irideæ*, *Liliaceæ*, etc.) change the whole country, which looked barren during the summer, into a garden of flowers.

2. **The South-Eastern Region.**—Travelling eastward from Zitzikamma, one notices a gradual change in the vegetation. Among the shrubs and trees many new kinds become conspicuous, some of them with handsome foliage and showy flowers, e.g. *Erythrina*, *Schotia*, *Calodendron*, *Dombeya*, *Gardenia*, and many more. *Rubiaceæ*, *Acanthaceæ*, and *Asclepiadaceæ* become more numerous, and new forms of plants appear, e.g. Palms (*Phoenix reclinata*), *Cycadaceæ* (*Encephalartos*), and the beautiful *Strelitzia*. The epiphytic orchids and tree-ferns, which were represented by a few species only in the Knysna forests, become more numerous, and tree-like *Euphorbias* and *Aloes*, e.g. *E. grandident*, *A. Bainesii*, inhabit the hillsides.

In the coast-lands the flora is quite sub-tropical, and gradually verges into real tropical vegetation.

3. **The Central Region** is bounded in the south-west and east by the two regions just described, and includes Little Namaqualand, but not Bushmanland.

In passing from the coast-lands through one of the mountain passes, e.g. Hex River valley, one notices that

the vegetation changes almost suddenly. The Proteaceæ, Rutaceæ, and Heaths disappear entirely, while succulents and Composites appear in large numbers. The genera *Mesembryanthemum*, *Crassula*, and *Cotyledon* are conspicuous everywhere, some species growing socially—a rare occurrence in the flora of South Africa—and covering large tracts. *Acacia horrida* (Karoothorn), *Portulacaria afra* (Spekboom), *Capparis oleoides* (Witstam), *Sarcocaulon* (Candlebush), and *Testudinaria* (Elephant's-foot), are a few of the more curious forms of plants of this region, all of them adapted in a peculiar way to the extremes of the climate, especially to the long periods of drought. The Composites abound, particularly in the northern part of the region, where they often predominate so largely as to almost exclude all other vegetation. Fortunately, a few of the most common Composites are excellent food for small stock, and sheep-breeding would be next to impossible in these districts without the little "Pentzia" bushes (*P. virgata*). There is one foreign plant which already has conquered large areas, and is still spreading, viz. the Prickly Pear (*Opuntia tuna*), a native of Central America.

4. **The Kalahari Region** extends from the Orange River northwards into the tropics, and includes Bushmanland on the left bank of the river. In the Northern Transvaal the flora of this and of the subtropical regions pass gradually into each other. Only a small part of it, viz. the western coast-strip, deserves the name "desert;" by far the greater part is a grass country with isolated shrubs and trees. The grass grows in tufts like wheat, and often stands so high and so thick that miles and miles of country look like waving cornfields. Next to the Grasses the Acacias are the most characteristic element of its vegetation. Besides the common *A. horrida*, which has spread as far south as the Cape Peninsula, we notice mostly *A. Giraffæ* (Camelthorn), a most beautiful tree, and *A. detinens* (Hookthorn), a shrub with sharp-pointed recurved spines, which no traveller forgets who has had to pass through a thicket of this Acacia.

In the northern part of this region, near Walfish Bay, occur two most curious plants, viz. the *Welwitschia mirabilis*

(Gnetaceæ) and *Acanthosicyos horrida* (Cucurbitaceæ), the fruit of which, called "Naras," forms the staple food of the Topnaars, a tribe of Hottentots.

For fuller information on this subject, see Mr. Bolus' essay on the "Flora of South Africa," in the "Official Handbook of the Cape of Good Hope, 1886."

CHAPTER XIX.

A FEW HINTS ON MICROSCOPIC WORK.

IN order to be able to understand the physiology of plant-life, it is absolutely necessary that the student should be acquainted with the elements of vegetable anatomy. This knowledge he cannot acquire without some practical work at the microscope.

Students who have not the assistance of a teacher must use one of the smaller guides, *e.g.* Bower, "Practical Instruction in Botany," or Strassburger-Hillhouse, "Handbook of Practical Botany;" but as these books contain much more than the beginner, for whom this little book is written, requires, a short index of the more important points and the materials to be employed will be useful.

I. INSTRUMENTS WANTED.

Besides a good microscope, which should be provided with a one-inch and a one-quarter inch objectives, only a few glass slips, cover-glasses, glass rods for the reagents, needles fixed in wooden handles, a penknife, forceps, and razor, are required.

2. REAGENTS.

Sulphuric Acid.—The concentrated pure acid causes cell walls to swell. It is very corrosive, hence care must be taken not to bring it in contact with the lens or the body.

Caustic Potash.—The dilute solution (5 per cent.) as kept by chemists. Useful for clearing preparations, as it causes the cell walls to swell.

Iodine.—Dilute the "liquor iodi" of the chemists with water until it has a dark sherry colour. Stains starch blue and

cellulose yellow, but this yellow is changed into blue on the addition of conc. sulphuric acid.

Schulze's Solution (*Chlor-zinc-iodine*) ($\text{ZnCl}_2 + \text{KI} + \text{I}$).—Stains cellulose blue, but corky and lignified cell walls yellow.

3. MATERIALS.

Starch Grains.—A little Wheat flour. Thin section of Potato. Thin section of Bean. A drop of the milky juice of a Euphorbia, e.g. *E. helioscopia*, a common garden weed, or *E. caput medusæ*. Observe first in water, then after adding iodine.

Crystals.—Oxalate of lime in single crystals (monoclinic prisms, fig. 12), and as cluster-crystals in the leaves, and specially the stalks of Oxalis. As bundles of raphides (very common) in the green tissue of the Prickly Pear, or the leaves of Aloe, Agave, etc.

Inuline.—Place a piece of Dahlia-root in strong spirits of wine for a few days, and examine sections in alcohol.

Pollen Grains.—Observe first in air, then in alcohol, then in solution of sugar (2 per cent.).

Chlorophyll Grains.—A section of any leaf will do. Also examine some fresh algæ (green slimy threads) from water-courses or pools. Many kinds, e.g. *Spirogyra*, have chlorophyll-bands, not grains.

Cell-structure.—A little yeast. Observe in water, then stain with iodine, then with Schultze's solution. Note the nucleus. Compare with cells of algæ.

Thickened Cell Walls.—The seeds of Gladiolus, Amaryllis, Ornithogalum, Aloe, etc., possess a large endosperm, which consists of cells with thickened and pitted walls. The shell of the seeds of the Guava and Prickly Pear consists of sclerenchyma. Collenchyma may be well seen in the leaf-stalks of Begonia. Bordered pits are best studied in young shoots of Pines.

Hairs.—Root-hairs on young Wheat, Maize, or Bean plants. Simple unicellular hairs on Quince leaves, Apricot-skin, Pelargonium, etc. Multicellular hairs on the stalk of the Sunflower or the Silver-leaf. Branched hairs on the leaves and stems of

the garden "Hocks." Stellate hairs on many species of *Solanum* and *Hibiscus urens*. Note the differences in their mode of insertion. The glandular hairs of the Sundew and the stinging hairs of the Nettle are of a more complicated structure.

Circulation of Protoplasm.—Take a very young shoot of a Pumpkin or Melon, preferably in bright sunlight, and quickly place a hair from its terminal bud in a drop of water on the slide. The hairs on the stamens of *Bulbine* are also suitable when taken from flowers which are just opening in sunlight.

Vessels.—Longitudinal sections through any young stalk, e.g. Sunflower, Bean, etc., will show the different kinds.

Laticiferous Vessels.—Root of *Scorzonera* or *Chicory*. Stems of *Euphorbia*. Make radial and tangential sections, observe in water, then in iodine, then in Schulze's solution. Use specimens preserved in alcohol.

Stomata. Structure of Leaf.—Detach a scrap of the epidermis (a colourless film) of a leaf of *Hæmanthus*, *Ornithogalum*, or any larger orchid, and place it in water. Note the outlines of the cells and the position of the stomata. Cut a fine film from the underside of an orange-leaf, and note the difference in the outline of the cells and position of stomata. Take a leaf of maidenhair and examine it. Make a transverse section of the Orange-leaf (place a small piece in a slit made in a piece of Elder-pith soaked in water) and one of an Aloe-leaf. Note the position of the stomata and their structure. Compare sections through the two kinds of leaves on the Blue-gum (*Eucalyptus*), i.e. the sessile leaf of young plants and the hanging sickle-shaped leaf of older trees (one is symmetrical and one bifacial). Also note the peculiar structure of the layer of wax on the epidermis.

Structure of Stems.

A. Monocotyledons.—Stalk of Maize. Transverse section through an internode, kept in alcohol for a few days. Place it in Schulze's solution, and examine with a low power. Notice the scattered fibro-vascular bundles and the fundamental tissue. Examine one bundle as to its constituents by the higher power. Also make longitudinal and radial sections, and examine the

elements of the xylem, cambium, and phloem. Study stem of Orchid in the same way.

B. *Dicotyledons*.—Stalk of Sunflower, preferably from alcohol. Transverse and longitudinal sections to be treated with Schulze's solution. Young twig of Clematis, Honeysuckle, or Passion-flower. Young twigs of Oak and Blue-gum, also of Pine. Compare each one with sections of branches one or two years old.

As a rule, the examination should be made at first with the lower power, the higher one to be used only for studying some details. Every object examined through the microscope should be drawn (lead pencil). This is the only way to teach the eye to see correctly. It is not necessary that all the details should be rendered (e.g. the granular contents of cells), nor that the drawing be artistic, as long as the outlines and all that is drawn is correct.

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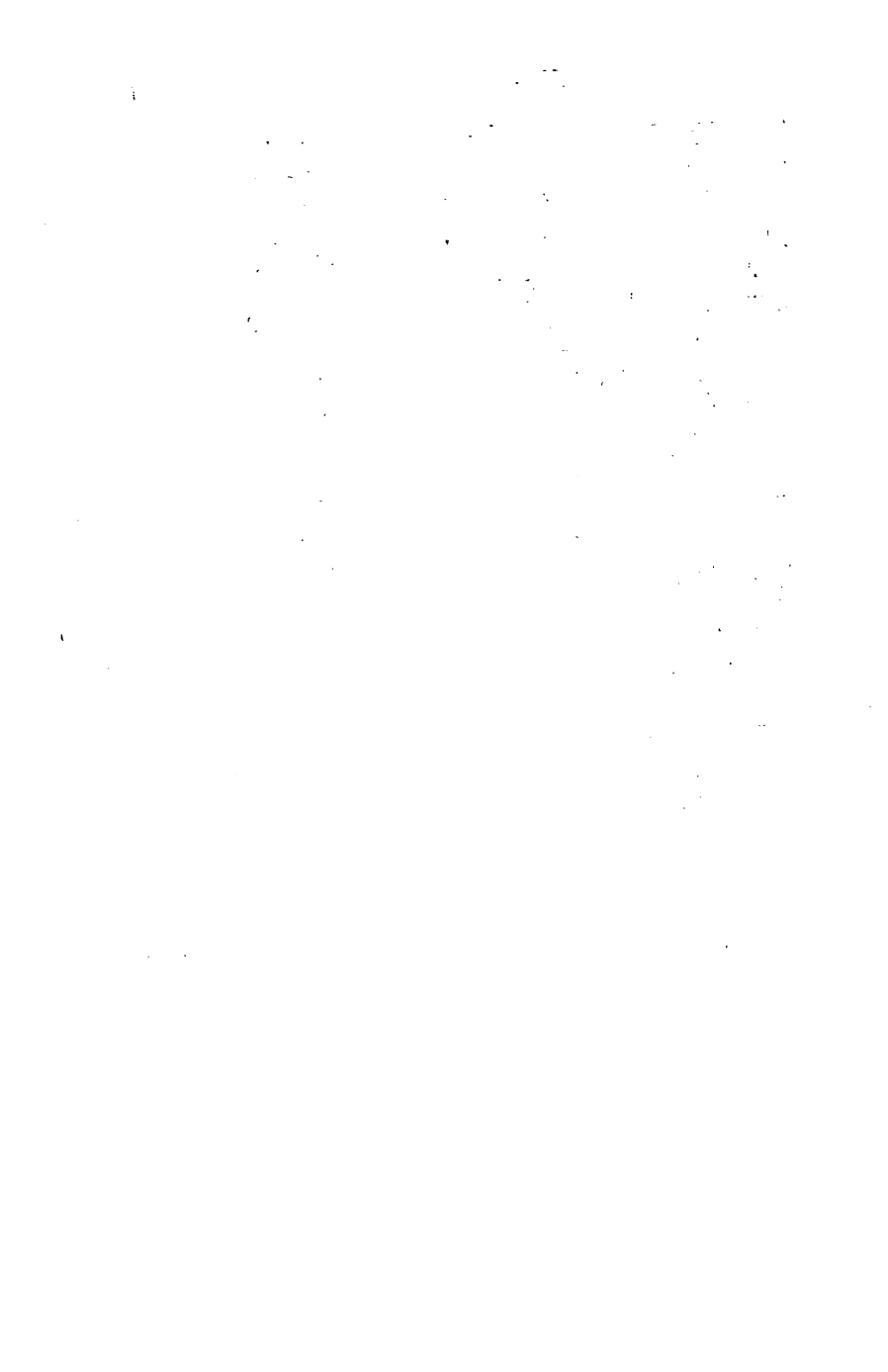
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